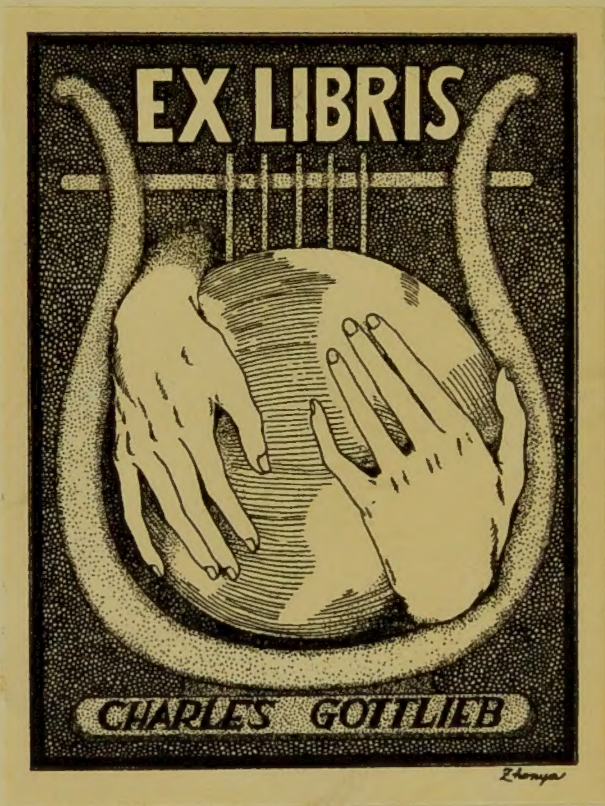
RADIOTHERAPY

BELOT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RADIOTHERAPY IN SKIN DISEASE

RADIOTHERAPY IN SKIN DISEASE

BY

DR. J. BELOT.

WITH A PREFACE BY DR. L. BROCQ,
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TRANSLATOR'S PREFACE

The growth of radiotherapy is so phenomenal, and its future is so full of promise, that any new light on the subject is eagerly welcomed.

I am therefore pleased to present *Dr. Belot's* well-known work to English readers. It has been most favourably received on the Continent, and has already reached a second edition.

Both as a physician and an electrician, *Dr. Belot* is an acknowledged expert. I am fortunate in having his cordial co-operation in the production of this translation, and can only regret that the clearness and grace of the original are so unworthily reproduced in an English dress.

W. DEANE BUTCHER.

EALING, 1905.

PREFACE

Radiology was born but yesterday ; it has already made enormous strides. To-day it may be said to dominate the therapeutics of dermatology.

I have long been desirous of testing practically what electrotherapy is able to accomplish in the treatment of skin diseases, and for nearly eight years I have occupied myself at my polyclinic in verifying the results published by electrical specialists.

When, in the years 1901 and 1902, radiotherapy began to make such marvellous advances in Germany, in England, and in America, I asked my colleague *Dr. Bisserié*, who was then in charge of the electrical department of the Hôpital Broca, to turn his attention to the subject. He was, however, only able to carry out some preliminary experiments.

Later on we found in *Dr. Belot* at once an electrician, a mechanician, and a physician, a most enthusiastic investigator of the new science, and one who had the necessary leisure to be able to devote himself exclusively to the work.

To-day *Dr. Belot* gives us the results of his researches and therapeutic experiments, a work which was commenced as a modest essay on epilation by the X-rays, and has developed into a complete treatise on the practice of radiology in France.

I am proud and happy that this book took its origin in the work of my modest electrotherapeutic clinique on the left bank of the Seine, and that its production has been aided by the kind and disinterested assistance of my friend *Dr. Béclère*, an acknowledged master of the subject. This work of *Dr. Belot's* is no mere compilation. Not only has he consulted the many works which have appeared on the subject, and collected with assiduous care the facts and theories which have inundated the press : he has added to

our knowledge by careful observation and original work. He has invented new apparatus, he has verified the instruments of measurement, he has patiently watched the sick under his care, and, after many endeavours, he has finally determined the technique to be followed in the treatment of each affection.

To this task he has brought talents of no mean order. Aided by the ripe experience of *Dr. Bisserié*, who has lent him his cordial assistance, *Dr. Belot* has produced a work of great originality—complete, practical, and of the highest scientific importance.

L. BROCQ.

July, 1904.

INTRODUCTION

The first idea of this work was due to *Dr. Brocq*, who was desirous of ascertaining for himself the therapeutic achievements of radiotherapy. For this purpose he instituted a series of experiments in his laboratory at the Hôpital Broca. At that time radiotherapy was but little developed, at all events in France, and had barely issued from the stage of empiricism.

Our knowledge of the subject was very incomplete. We had to learn before we could practise, and for this we turned to a great teacher, *Dr. Béclère.* He most kindly placed both his books and his experience at our disposal, and further allowed us to make our first experiments, under his own direction, in his laboratory at the hospital of St. Antoine. There he demonstrated his technique and its results, and introduced to us those instruments of exact measurement without which radiotherapy could never have become an exact science. Imbued with his wise counsels, we began our first independent experiments at the Hôpital Broca. We took great pains to proceed methodically, and the results obtained soon showed that we were on the right road. When, at various times, difficult problems confronted us, it was to *Dr. Béclère* that we turned for help. We take this opportunity of expressing our gratitude for the invariable kindness with which he assisted us.

Very soon the apparatus at our disposal proved insufficient. The number of patients increased, and a second installation became necessary. *Dr. Brocq* did all in his power to assist us in this matter, and we are happy to be able to thank him for the interest which he has shown in our work and the wise counsels which he has given us.

We have also to thank *Dr. Bisserié* for his kindness in communicating to us notes of cases treated privately by him.

We have endeavoured to make this work essentially practical, and have added only so much technical matter as is indispensable to any medical man desirous of practising radiotherapy. We have devoted as much space as possible to its clinical application, and have limited our attention solely to the Roentgen rays, omitting all mention of radiations from radio-active bodies. These phenomena constitute a different branch of the science, which we may call radium-therapy. Although successful results have been reported with this agent, they are at present too few to warrant us in the expectation that radio-active substances will ever replace the Crookes tube. Moreover, the special rays which produce the therapeutic effects of radium are analogous to X-rays, and have similar physiological properties.

This work is divided into three parts.

In the first part, after giving the history of Roentgen's discovery, we pass in review the different forms of apparatus capable of producing the Roentgen rays. We shall not attempt to enumerate or describe all the forms, and for further details must refer the reader to *Professor Bouchard's* 'Traité de Radiologie Médicale.' Instruments of measurement are the subject of a more careful study, and we close with a review of the properties of the Roentgen rays and of the hypotheses as to their nature.

The second part opens with a study of the nature of the radiations from an X-ray tube. After having shown that it is the X-rays alone which are therapeutically active, we discuss the principal factors which govern their application.

The third part, purely clinical, treats of the various dermatoses in which radiotherapy has been employed. From the results of direct experiments we deduce the dosage which appears to give the best results. Leaving for a moment the realm of dermatology proper, we next give an appreciation of the treatment of deep-seated cancer by means of the Roentgen rays.

This work is the result of many years of radiotherapeutic practice, and includes reports of patients treated at the Hôpital Broca from March, 1903, to June, 1904. *Dr. Brocq* is responsible for the diagnoses, the patients being under his supervision. Several doubtful diagnoses were confirmed by histological examination, and many of the successful cases were shown at the Société de Dermatologie. In general the results have been very successful, and if in certain

cases we have not cured the patients, the treatment has in no instance proved detrimental. Serious accidents have been obviated by the methodical use of precise measurements, which has enabled us to attain the exact degree of reaction that we desire.

J. BELOT.

DR. BROCQ'S LABORATORY,
HÔPITAL BROCA,
June 1, 1904.

The welcome which the medical profession has accorded to our work has necessitated the issue of a second edition a few months after the first.

In this edition we have endeavoured to fill any lacunæ which may have escaped our notice in the first, and have added several new illustrations.

Further, we have taken notice of the radiotherapeutic work which has appeared during the last few months in France and in other countries.

We have not entered into the question of deep-seated cancer, as we have undertaken a series of experiments on that subject, and hope soon to be able to give our readers the results of our personal experience.

J. BELOT.

December, 1904.

RADIOTHERAPY IN SKIN DISEASE

PART I

CHAPTER I.

HISTORICAL REVIEW OF ROENTGEN'S DISCOVERY

Towards the end of 1895 *Professor Roentgen*, of the University of Würzburg, whilst experimenting on the phenomena of the Crookes tube, discovered a new kind of radiation, invisible to the eye, but capable of affecting a photographic plate. These rays possessed the curious property of traversing bodies generally regarded as opaque.

Long before this, experiments had been made on the phenomena of electric discharge through rarified gases. Numerous discoveries had preceded that of *Roentgen*, and it may be interesting to pass these rapidly in review. For this purpose we shall borrow from the article by *M. Bertin-Sans*, which appeared in *Bouchard's* 'Traité de Radiologie Médicale.'

As long ago as the eighteenth century we meet with observations on the subject. The *Abbé Nollet*, in studying the spark discharge from an electrical machine, arranged an apparatus so that the spark should pass through a glass globe which could be gradually exhausted. He observed a curious phenomenon: little by little, as the pressure in the globe decreased, the spark, a mere narrow thread of light at ordinary pressures, broadened out.

From this he came to the conclusion that the electric fluid circulated more easily in a vacuum than in air, igniting the rarified gas more readily. We may note in passing that the apparatus used by the Abbé is in principle the same as that employed at the present day for the production of X-rays.

The glass tube has been perfected in form, the sparking knobs

have been replaced by anode and cathode of special form, and a much more powerful generator of electricity is employed; but the essential apparatus is still merely a closed vessel, almost exhausted of air, through which an electric discharge takes place.

Further observations followed that of *Nollet*. It was found that as the pressure within the tube diminished the luminous phenomena were modified.

The sparks broaden out into shimmering aigrettes, which fill the whole space from knob to knob, without any apparent discontinuity. When the gas is sufficiently rarified, the aigrettes are further changed into a continuous glow. This brilliant glow which surrounds each knob varies in colour with the nature of the gas employed, and a dark space is seen between the knobs.

In 1843, *Abria* of Bordeaux obtained a vacuum with a pressure of only 1 or 2 millimetres of mercury. The electric egg as his apparatus was called was driven by a Ruhmkorff coil. At this exceedingly low pressure the appearance of the luminous phenomena was modified. A dark space appeared at the negative pole, while the glow from the positive pole spread out until it filled the rest of the tube. This dark zone had already been described by *Faraday*. *Abria* was the first to observe the alternate light and dark striæ which occupy the whole length of the luminous region.

Gassiot, *Spottiswoode*, and *Fernet* also investigated the phenomena of stratification.

Hittorff, who obtained a still more perfect vacuum, was the first to study the character of the electric discharge through highly rarified gases. *Goldstein* also investigated the same subject.

About the same time, 1879, the English physicist *Sir William Crookes* produced still higher vacua with a pressure of only a few millionths of an atmosphere. In the Crookes tube the electric egg of the older experimenters is reduced to a simple tube of glass, the discharging knobs being replaced by platinum wires or aluminium discs.

Under these circumstances the luminous phenomena are greatly modified. In the immediate neighbourhood of the cathode or negative pole a dark space appears, bounded on the one side by the cathode itself, and on the other by a luminous margin. As the pressure of the gas decreases, the dark zone increases in extent, and finally occupies the whole space between the cathode and the

opposite wall of the tube which acts as an anticathode, the anode in this case being at the side of the tube.

The illumination which accompanies this discharge is not due directly to the passage of electricity, but to phosphorescence of the glass in the neighbourhood of the anticathode.

To explain these phenomena *Crookes* propounded his theory of bombardment. We quote *M. Bertin-Sans.*

'According to *Crookes*, at the degree of rarification obtained in these tubes the gaseous particles are quite independent of one another. They can traverse a rectilinear path of finite length without mutual collision, and the extent of the dark zone in front of the cathode is a measure of the mean free path of the particles under the existing conditions of pressure. *Masson* has clearly demonstrated that in the highest obtainable vacuum no electric discharge takes place. Hence we are led to believe that the gaseous particles still remaining in the tube are the medium of the discharge. On this hypothesis the discharge is a phenomenon of electric convection. The gaseous particles obtain a negative charge from the cathode, and are then repelled. Since their small number renders them free to follow unimpeded a rectilinear path, they finally bombard the opposite boundary of the tube. The fluorescence is the result of their mechanical action on the glass.'

Crookes devised various experiments to prove the truth of his hypothesis, among them the electric mill, which rotates under the impact of gaseous particles, and the mica cross which, when interposed in their path, throws a shadow on the fluorescing glass.

This invisible stream, issuing from the cathode in a direction normal to its surface—a direction entirely uninfluenced by the position of the anode—was named by *Wiedeman* the **cathode rays**. In opposition to *Crookes*' theory, *Wiedeman* advanced the hypothesis that these cathode rays were caused by ethereal vibrations of very short wave-length.

Their true nature has been much discussed, the prevailing opinion being that they are free **ions**, liberated by dissociation of the gas, charged with negative electricity, and moving with considerable velocity. Whether they are matter in motion, rays of light, or other analogous vibrations, it is certain that they carry a negative charge, and that their course may be deflected by the action of a magnet.

Both *Crookes* and *Goldstein* have studied the phenomena of

fluorescence due to the impact of cathode rays on various bodies. *Hertz* found that they pass through a piece of aluminium foil placed in the interior of the tube, although a sheet of mica will arrest them.

In 1893, *Lenard*, taking advantage of the transparency of aluminium to cathode rays, examined them outside the Crookes tube. In order to do this he inserted a window of thin aluminium foil in the glass opposite the cathode. The rays which have passed through this window cause many bodies to fluoresce, just as they do when placed within the tube. Further, these rays act on a photographic plate, they discharge electrified bodies, and after their exit from the tube they are able to traverse the most perfect vacuum which has as yet been obtained.

It was soon found that these radiations outside the tube were complex in character. *Lenard* showed that a part only were deviated by a magnet, the remainder being totally uninfluenced by the magnetic field. There were therefore issuing from the tube, radiations hitherto unrecognised. This second portion of the rays, unaffected by the magnetic field, was in fact composed of X-rays. *Lenard* may therefore be regarded as the first observer of these new rays. He it was who first recognised their existence, though he was unable to isolate them.

This was reserved for *Professor Roentgen.*

He was experimenting with a Crookes tube in his laboratory at Würzburg. The tube, which was enclosed in a cardboard box, had no metallic window. Whilst working with it, he noticed that some barium platinocyanide crystals which happened to be lying in its neighbourhood became luminous. This accident led to the discovery of the new rays.

Under their influence a screen of barium platinocyanide was found to be illuminated at a distance of more than 2 metres from the tube.

Roentgen next conceived the idea of replacing this screen by a photographic plate, and found that it was also affected by the rays. A thick piece of wood or a slab of ebonite failed to screen the plate from their action. Aluminium was found to be transparent, while lead was quite opaque to these rays. *Roentgen* showed that these results were not produced either by cathode rays or by ultra-violet light, but were due to a new type of radiation, which he modestly named the X-rays. He

discovered that these new rays emanated from those portions of the glass tube which fluoresced under the action of the cathode rays. They diverged in straight lines from every part of the fluorescent surface. Within the tube were only cathode rays, which when arrested by the glass wall caused it to fluoresce. It was the fluorescent glass which played the part of a transformer of energy, and gave rise to the X-rays.

The properties of the Roentgen rays were further investigated by their discoverer. He found that they passed through most bodies opaque to light with more or less facility, and that the transparency of any substance to the X-rays was closely related to its density.

Following up this discovery, *Roentgen* interposed his hand between the glowing tube and a sheet of cardboard covered with crystals of barium platinocyanide. A shadow of the hand appeared on the screen, and the darkness of the shadow was differentiated for the bones and the softer tissues. The denser bones stopped most of the rays, and showed as a black shadow. The softer parts were more easily traversed, and allowed most of the rays to pass through them, thus causing the screen to fluoresce feebly, so that the whole shadow was of a pale gray colour. The unshadowed portion of the screen fluoresced brilliantly. This was the birth of *radioscopy*.

Roentgen next replaced the fluorescent screen by a photographic plate. After a suitable exposure he developed it, and obtained a clear outline of the form of the hand, with a distinct silhouette of the bones. This was the origin of *radiography*.

The Roentgen rays are propagated through all media in straight lines with more or less absorption, but without diffraction. They cannot be reflected or refracted, are incapable of polarization, and have hitherto shown no interference phenomena. They are unaffected by a magnet or an electric field, but rapidly lower the potential of all electrified bodies in their neighbourhood. Invisible to the eye, they are only rendered apparent by the fluorescence which they are capable of exciting in various substances.

The memoir communicated by *Roentgen* to the Physico-Medical Society of Würzburg in December, 1895, aroused the greatest interest. Scientists all over the world welcomed the new discovery. In every country the experiments were repeated, and all other original work in the laboratories was suspended. 'What excited

the imagination,' says *M. Bertin-Sans*, 'was not so much the new theory of the electric discharge, as the discovery of a new procedure, as precise as it was unhoped-for, which enabled us to obtain a photograph of the skeleton and to perform an autopsy of the living body.'

The advance was now rapid. The power of the electric generators was increased, induction-coils were improved, and static machines were gradually brought into use. In 1896, *Jackson* constructed the first focus-tube by interposing a small platinum disc in the path of the cathode rays. By this arrangement the power of the tubes was considerably increased, and the duration of the exposure necessary to obtain a radiograph was reduced from thirty minutes to as many seconds. Many other scientists besides *Roentgen* set themselves to discover some theory which would explain these phenomena in accordance with accepted physical ideas.

In many cases during the course of experiments with X-rays, it was found that these radiations set up a peculiar reaction in the skin of the operator's hands. In some instances even more serious accidents occurred.

Schiff and *Freund* conceived the idea of employing this reaction in the treatment of disease. This was the origin of *radiotherapy*.

With increased knowledge of this new form of energy, it became possible to measure it both qualitatively and quantitatively, and thus an empirical and arbitrary procedure became a true science: for all science is based on accurate measurement.

We may now pass on to consider the method of producing the Roentgen rays. We propose to review the apparatus necessary for their production, and the means of measuring and regulating them, and finally, we shall briefly review their properties and some of the hypotheses which have been propounded as to their nature.

CHAPTER II

THE PRODUCTION OF X-RAYS

Two things are required for the production of X-rays:

Firstly, a source of high-tension electricity.

Secondly, a Crookes tube—*i.e*, an exhausted glass vessel with a high vacuum.

1. Sources of Electricity.

In order to force an electric discharge through a high vacuum tube and thus produce the cathode rays which are the generators of the Roentgen rays, we require an electric current of high tension, but of small magnitude.

Most sources of electric energy give a large current at a low potential. The static machine alone gives a current suitable for our purpose—*i.e.*, a weak current at high potential. This then is the only source which can be employed directly in the production of Roentgen rays.

If we wish to make use of other sources of electricity, we have to employ a transformer, which, as its name implies, transforms a large current at low potential into a small current at high potential, or *vice versa*. This transformation cannot be effected without loss of energy. The efficiency of a transformer is measured by the ratio of the electric energy given out to that supplied to it.

The typical transformer used for X-ray work is the induction-coil, or Ruhmkorff coil. This may be driven by a battery of primary cells, by accumulators, by a dynamo giving a direct current, or even, with a special subsidiary apparatus, by an alternating current.

DIRECT SOURCES OF ELECTRIC ENERGY.—STATIC MACHINES.

As is well known, there are three sources of power utilized to generate electric energy—viz., thermal, chemical, and electric.

Neither the thermal energy of the thermo-electric pile nor the chemical energy of the galvanic battery is capable of producing a current which will work the Roentgen tube directly; the electro-motive force is too small. Even the famous battery of *Warren de la Rue* and *Hugo Müller*, which consisted of 25,400 silver chloride cells, would be insufficient to drive a focus-tube.

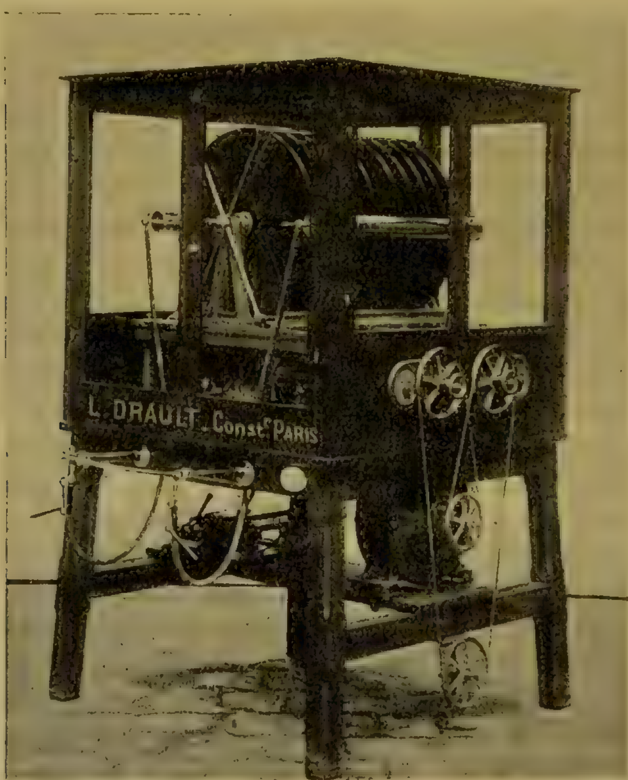


Fig. 1.—Static Machine with Twenty Plates.

The same may be said of dynamos: whether giving an alternating or a direct current, they cannot be used directly.

Static machines however are well adapted for this purpose, for they give a continuous current of high potential. They are of two types—the friction machine of *Ramsden*, and the influence machine.

Friction machines are not employed in practice. The form of influence machine generally used in France is of the *Wimshurst* type. It has been modified in many ways: the number of discs has

been increased and the condensers have been omitted, as have also the metallic sectors which were attached to the plates of the original instrument; friction brushes have been added; the discs are now made of ebonite, and the velocity of rotation has been greatly increased. The mechanical details have been improved, and to insure an equal rate of rotation to all the plates, the Drault Company now drives them by means of a single endless band. In order to protect it from dust and moisture, the machine is enclosed in a glass case; but care must be taken to open the glass doors when the apparatus is in use, to prevent damage to the insulation by the ozone generated.

In consequence of these improvements, the static machine is now equal, if not superior, to the coil for X-ray work. There are numerous excellent models of this apparatus by various makers.

As a means of rotating the machine, manual labour may be employed. It is better however to use some form of motor. The most convenient is an electric motor, mounted on the same stand as the machine. This may be driven from the public supply, whether continuous or alternating. The machine is worked by a belt or pulley attachment, the rate of rotation being adjusted by a regulating rheostat interposed in the circuit.

To produce X-rays, it is only necessary to connect the positive pole of this machine to the anode, and the negative pole to the cathode of the focus-tube. The following is a simple method of determining the polarity: The machine is set in motion and primed. On the surface of the plate, near one of the collectors, a violet glow of disc-like shape will be seen. This marks the negative pole.

Shortly after *Roentgen's* discovery, *Dr. Monell* of New York suggested the employment of static machines. *Destot* of Lyons, *Leduc* of Nantes, and *Bergonié* of Bordeaux, introduced improvements which adapt them for use in the production of X-rays.

Thanks to numerous recent improvements in their construction, static machines are in frequent use at the present day. They possess certain advantages over other forms of generators. They do not require an interruptor, which is always a source of trouble; they do not destroy the focus-tubes, as the current flows only in one direction; and their equable continuous current causes no flickering of the light. This last advantage is of great importance in radioscopy.

One objection to their use is their liability to get out of order. They need great care; they must be well protected from damp, and

should be used every day. The plates should be carefully wiped every morning, and taken to pieces and washed with 90 per cent. alcohol twice a week.

They are primed by touching one of the plates, at a little distance from the collectors, with the finger. If this is not sufficient, the tip of the finger may be dipped in amalgam and the process repeated.

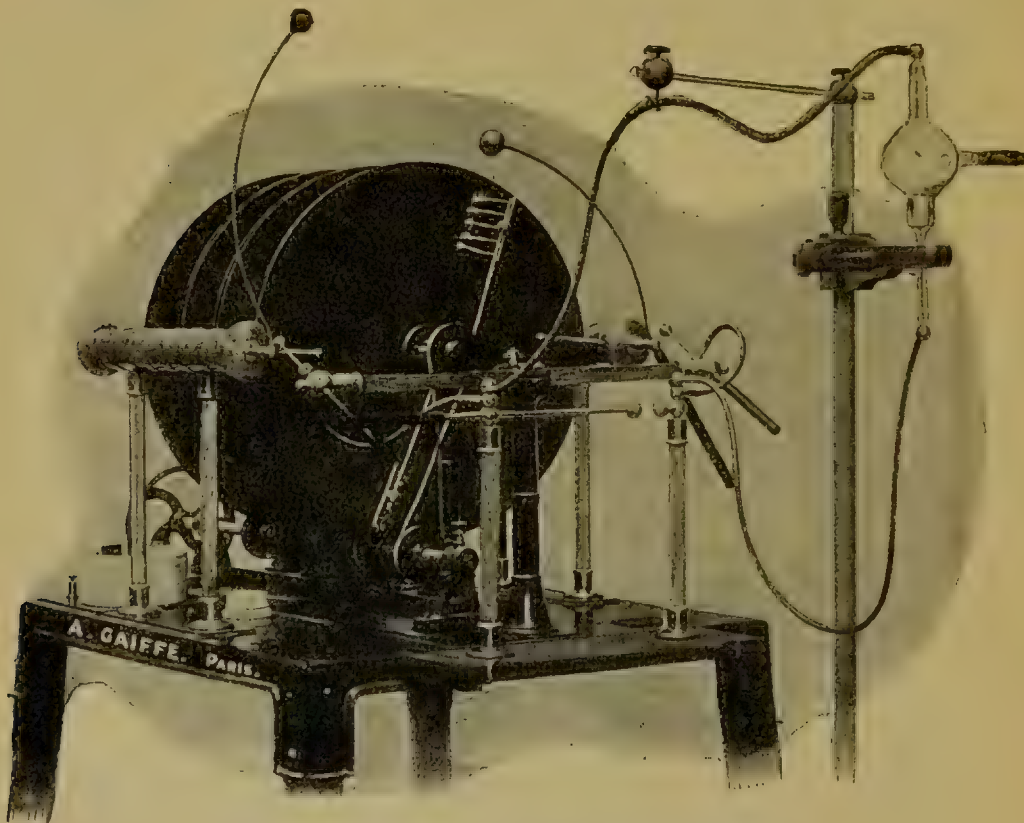


FIG. 2.—STATIC MACHINE WITH EIGHT PLATES.

Although much has been done, the static machine has not yet attained the highest possible degree of perfection. *Leduc* of Nantes has shown that the output of such a machine is proportional to the capacity of the condenser formed by its two plates. It therefore varies inversely as the distance between the external surfaces, and directly with their dielectric coefficient. He says:

'These conditions seem to have been generally realized by the makers. They have endeavoured to bring the external surfaces of the plates as close together as possible, and to make them of a

material of high dielectric coefficiency. Still, it seems to me that a further improvement on these lines would increase the output of a Wimshurst machine from ten to twenty fold. This result would be obtained by reducing the distance between the armatures and by employing mica as the dielectric. Hitherto in the construction of Wimshurst machines the plate has to play a double part: it has been at the same time the dielectric of a condenser and the support of the revolving armatures. These functions should be separated. The condensers may then be made as thin as may be desirable, and of any desired substance, such as mica. The plate, being merely a support, may then be made thick enough to withstand a much more rapid rotation.

'The metallic sectors would be attached to the inner, instead of the outer surface of the plates, and covered with thin sheets of mica. The brushes situated as before would collect the electric charge from the armatures by means of studs and metal pins passing through the plate. The armatures would in this case be separated merely by two thin sheets of mica and the thinnest possible layer of air. The strong supporting plates might revolve with great velocity, and such a machine may be expected to give results which will make this a new form of electric generator.'

We hope that in the near future *Leduc's* anticipations may be realized.

INDIRECT SOURCES OF ELECTRIC ENERGY.

Induction-Coils.—The transformer generally used for raising the potential of an electric current is the ordinary induction or Ruhmkorff coil, which is seen in most physical laboratories. This apparatus enables us to obtain a secondary current of high potential, by means of a strong primary current of small voltage.

The phenomenon of induction was discovered by *Faraday*, and may be stated as follows:

When an electric current starts, increases, or approaches another circuit placed near it, a momentary current in the opposite direction is induced in the latter. When on the other hand the primary current stops, decreases, or is moved away, a current in the same direction is induced in the secondary circuit.

A Ruhmkorff coil consists of an inner coil for the inducing current, and an outer coil for the induced current.

The former is composed of two or three layers of thick insulated wire wound round a cylindrical core of soft iron. This carries the primary current. The secondary consists of numerous layers of fine insulated wire wound outside the primary coil, the two ends of the wire being attached to the terminals of the apparatus.

When the current which passes through the primary coil is rendered intermittent by means of an interruptor, it induces in the surrounding coils a current of high potential in the direct and reverse directions alternately.

There are various differences in the appearance of these machines, in the methods of winding, the kind of insulation used, and the output of the coil, each maker having his own specialities of construction.

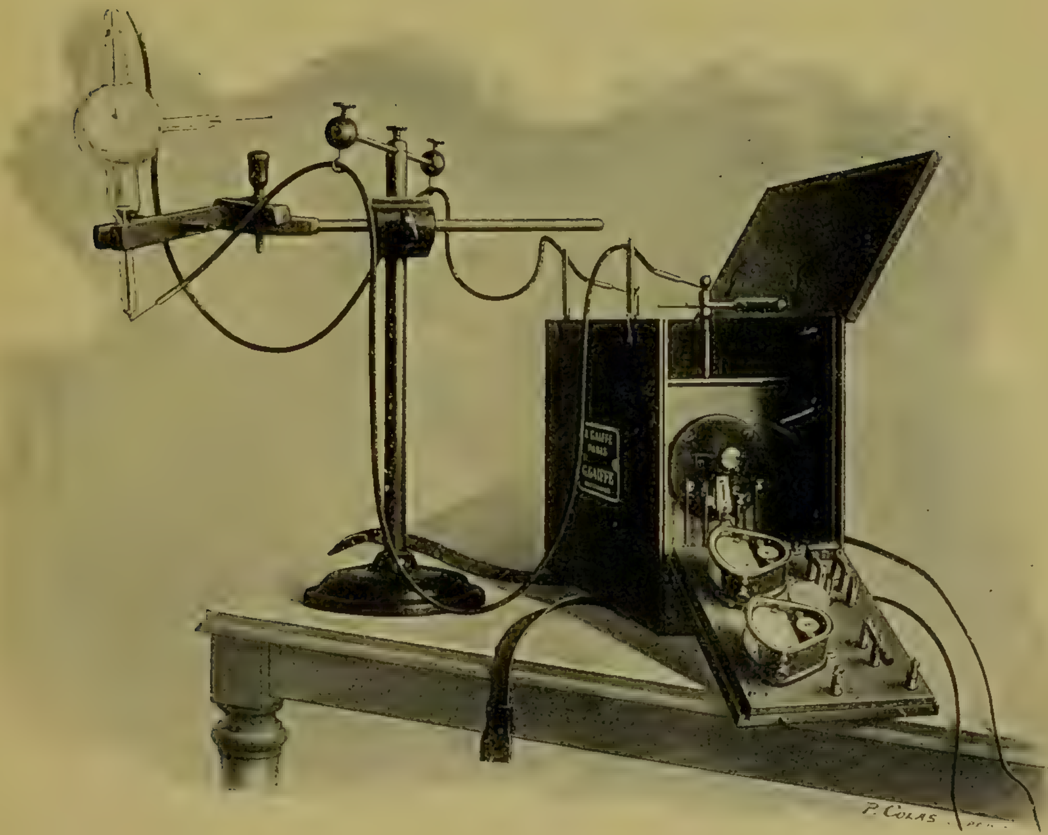
To obtain the best results, a well-made coil should be chosen, with due regard to the force at disposal. Even then the coil may break down in consequence of a spark passing between two turns of the secondary and piercing the insulating material. Such an accident is due either to the production of too large a difference of potential between two neighbouring points of the outer coil, or to reflection of the Hertzian waves arising within the coil. This may cause the complete or partial destruction of the coil, owing to short-circuiting of the current, the resistance of the whole length of wire between the two points being suppressed. For radiotherapy, a coil should be used giving a spark of at least 10 inches, or better still, 12 to 14 inches. Excellent instruments are constructed by Rochefort and Gaiffe.

A portable apparatus is made by Gaiffe, which is very convenient for those who require to take their machine from place to place. It contains a small coil, interruptor, rheostat, voltmeter, and ampèremeter enclosed in a neat wooden box. It is driven by three or four accumulators. The atonic break, invented by Carpentier, gives an equable illumination of the focus-tube, comparable with that obtained with a static machine. Its only disadvantage is the somewhat rapid wear of the platinum contacts.

In order to estimate the output of a coil, the following formula gives the coefficient of transformation. If I and I' are the currents in the primary and secondary coils respectively, and n and n' the length of the two coils,

$$\frac{I}{I'} = \frac{n}{n'}$$

PLATE I.



PORTABLE COIL (OPEN AND SHUT).

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This expresses the fact that the coefficient is equal to the ratio of the number of spirals in the two circuits. This formula is only approximately correct for coils having a soft iron core, and is moreover of only theoretical interest.

Condensers.—There is usually a condenser attached to each coil. This is often placed within the wooden stand, but is sometimes mounted separately. It consists of a number of sheets of tinfoil, insulated from each other by a dielectric.

The odd plates are electrically connected and joined to one of the terminals of the primary coil, the even plates being connected to the other terminal. The object of this condenser is to diminish the 'make' current, and also to rapidly neutralize the magnetization of the iron core. The following is the explanation of its action: The extra current produced in the primary circuit on 'break' spreads to the condenser and charges it. This at once discharges itself through the primary circuit, thus sending a current in the opposite direction which rapidly demagnetizes the core. By this means also we are enabled to diminish the spark of the interruptor at 'break,' since part of the current which causes it goes to charge the condenser.

In the larger coils the capacity of the condenser may be varied at will by means of special commutators.

The construction of induction-coils has not made the progress we might have expected, and recent improvements have not been of any great value.

Probably the chief cause of this comparative stagnation is the fact that the phenomena involved vary so rapidly that they cannot be measured by ordinary means. It is therefore impossible to establish a theory on which to base the necessary conditions of improvement. In the meantime improvement in the manufacture of coils has not kept pace with that of ordinary industrial apparatus.

Primary Current.—To drive an induction-coil, we need an electric current which satisfies certain conditions. It must be always in the same direction, and must be rendered intermittent by means of a specially-constructed interruptor.

We will now proceed to enumerate the sources of current which are of practical use.

1. *Continuous Currents.*

(*a*) *Galvanic Cells.*—Ordinary galvanic cells may be used to furnish the necessary current, but this is not a good method. Neither Bunsen cells, bichromate cells, nor even the famous two-fluid cells brought forward in the early days of radiography are of much practical use. They are quickly polarized, extravagant in use, and difficult to keep in order. In case of need, when nothing else is available, a strong bichromate battery may be used, but the results obtained are not satisfactory.

(*b*) *Accumulators.*—Accumulators are far preferable to primary cells. When once charged, they are always ready for use, and their output is sensibly constant. The improvements recently made in their construction assure them a long life. Their electromotive force is about 2 volts per cell, and their capacity varies with the size and surface of the plates. Two batteries are required, each sufficient to drive the coil, in order that while one is in use the other may be sent to be recharged.

(*c*) *Continuous Current from the public mains.*—The continuous current from the city supply may be employed directly. Its electro-motive force is practically constant, and it is always at hand when required. As it is usually delivered at a pressure of 110 volts, care must be taken that the coil is constructed for this voltage.

The current through the focus-tube may be regulated by interposing an adjustable rheostat in the primary circuit, thus enabling us to increase or diminish the inducing current. If there is no public supply available, we may use a small dynamo, driven by a gas or petrol motor. Such an arrangement may be used to charge accumulators, from which the current may be supplied to the induction-coil. It may also be driven directly from the dynamo, but this is not a good arrangement.

Whatever the source of electricity, a voltmeter and an aperiodic ampèremeter interposed between the coil and the interruptor, will give an approximate indication of the average strength and voltage of the current passing through the primary. These values may be kept constant during the duration of a radiotherapeutic exposure by means of a regulating rheostat.

2. *Alternating Currents—Monophase.*

The alternating currents supplied by the public mains are not of sufficient tension to work a Crookes tube.

They may however be used for the production of X-rays by either of the following methods:

The first is to transform the alternating into a direct current, and to use the latter to drive the Ruhmkorff coil.

Two instruments may be used for this purpose: electric valves and rotary transformers, or commutators.

The electric valve is a voltmeter, one electrode of which is made of aluminium and the other of any other metal. When the aluminium is the cathode, the current will pass with ease. When, on the other hand, the aluminium is the anode, the current passes with great difficulty. The voltmeter can then withstand a difference of potential of from 20 volts (with acid electrolyte) up to 140 volts (with alkaline electrolyte), without allowing a current to pass. This is due to the formation of a thin protective layer of alumina on the anode. The electric valve thus formed only allows one phase of the alternating current to pass, thus producing a direct interrupted current.

For the production of a steady continuous current, it is much better to make use of the rotary transformer.

This consists of a motor, driven by the alternating current and coupled to a dynamo, which generates a continuous current. The process is much simplified by the construction of the *dynamo-converter*. In this machine the primary is composed of a single coil. The secondary, also composed of a single coil, receives on one side the alternating motive current, while on the other side a continuous current is picked up by a system of collectors.

A second method is to use the alternating current directly. To do this a special apparatus is needed to rectify the current, since an alternating current as such cannot work a coil properly. The ordinary interruptor is replaced by one of a specialized form, such as that of Villard or Wehnelt.

An interruptor placed in the primary circuit of the coil may be so timed that the circuit is always opened or closed during the same phase. The resulting effect will be the same as that of an interrupted direct current. This is the principle of Villard's interruptor.

Under favourable circumstances it gives results as satisfactory as those obtained by the use of a direct current and an ordinary interruptor. It is however difficult to regulate. It needs careful synchronizing with the periodicity of the supply current, and any slight variation of period in the mains reacts on it.

Wehnelt's electrolytic interruptor gives similar results. Interposed in an alternating circuit, it arrests the current during alternate semiperiods. During the opposite semiperiod, when the

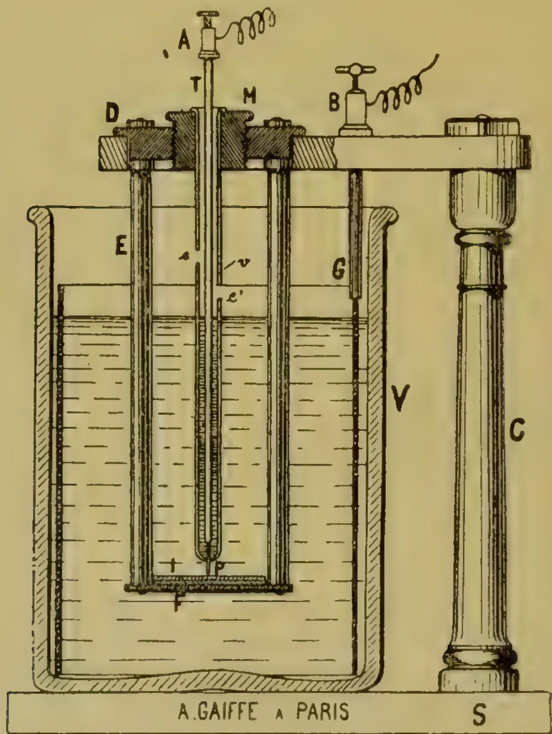


FIG. 3.—WEHNELT'S INTERRUPTOR.

platinum point becomes negatively charged, the current passes freely.

This apparatus has been repeatedly modified and improved. The illustration gives the modification adopted by Gaiffe. The immersion of the platinum wire is capable of regulation, and the wear is automatically compensated. Simon and Caldwell have done away with the platinum wire entirely, using instead a glass tube with a small orifice. This appears to work well. For a further description the reader is referred to special works on the subject.

Electrolytic interruptors have not in general answered the expectations which they at first excited. They are often difficult to regulate, and the consumption of electric force is considerable. On the other hand, the co-efficient of utility of a coil—*i.e.*, the quantity of electricity supplied to the secondary circuit during a given time—is greater with electrolytic interruptors than with most others.

3. *Alternating Currents—Polyphase.*

In some towns the current delivered is triphase or polyphase. A triphase current may be employed by using a Wehnelt's interruptor and Delezinier's phase-separator; or the current may be converted into a direct one by means of an electro-generator or commutator, the direct current driving the coil. A polyphase current can only be transformed into a continuous current by means of a commutator.

Interruptors.—A Ruhmkorff coil can only be used when it is furnished with an apparatus which will interrupt the continuous current a certain number of times per second. We have already described the two types of interruptor designed for use with alternating currents; we will not, therefore, refer to them again.

There are innumerable varieties of interruptors for continuous currents. The oldest of these is the trembler, but this is not adapted for the more powerful modern coils. At low pressures however Carpentier's atonic interruptor may often be used advantageously. It is a modification of the old-fashioned trembler of Neef, and retains his contrivance of platinum contact-points.

The principal advantages of this interruptor are:

(*a*) It has no definite period of vibration of its own, and may therefore be so adjusted as to give the greatest frequency of break compatible with the electro-motive force of the source and the self-induction of the primary, thus furnishing a maximum length of spark.

(*b*) It gives an instantaneous, and therefore a very efficacious break.

Interruptors may be classed under two headings—mechanical and electrolytic. The latter are mainly used for alternating currents. The former are of numerous types, which vary in detail. They usually consist of a small electro-motor, which works the mechanism that makes and breaks the circuit. They are regu-

lated by varying the rate of rotation of the motor, thus enabling us to increase or diminish the number of interruptions per second, and also, by means of an additional adjustment, to vary the time during which the current passes between the interruptions. Rochefort's interruptor is a good type for a small installation. That of Contremoulin, made by Gaiffe, is also very good, but it needs a pressure of at least 30 volts. The turbine interruptors, so much used in Germany, are also very satisfactory. All interruptors, of whatever type, are very delicate and irregular in their

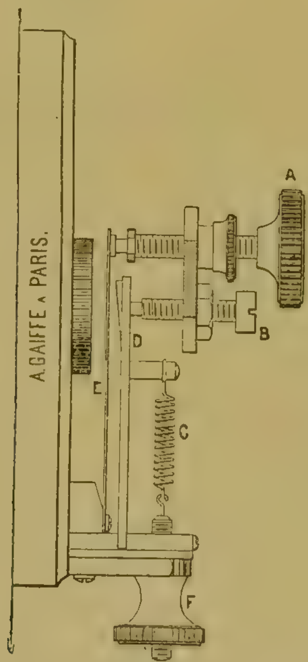
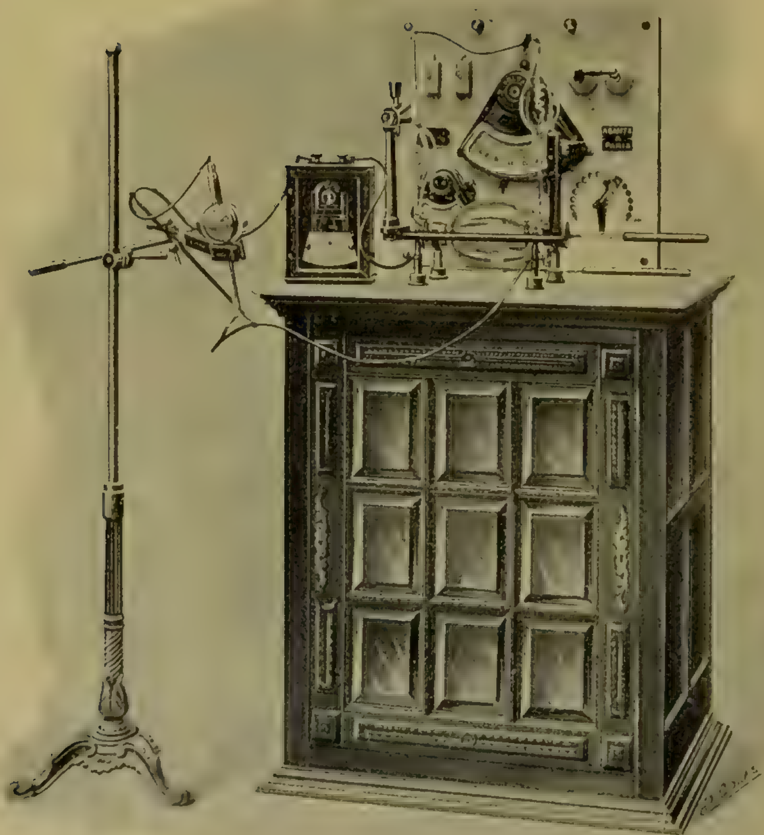


Fig. 4.—Carpentier's Atonic Interruptor.

action; hence the exact determination of the phenomena in a working coil is extremely difficult.

Transformers with Closed Magnetic Circuit for Alternating Currents. — A comparatively simple arrangement for utilizing alternating currents has been devised by *Villard.* The alternating main current, at 110 volts, passes through a transformer with closed magnetic circuit of the ordinary commercial type. A pressure of about 50,000 volts is thus obtained between the terminals of the secondary. These are connected to the armatures of two condensers, the other arma-

PLATE II.



TRANSFORMER WITH CLOSED MAGNETIC CIRCUIT, FOR X RAYS AND HIGH-FREQUENCY CURRENTS.

To face p. 10.

tures being connected to the Crookes tube. A Villard valve and a spintermeter are also interposed in the circuit. The discharge passes alternately through the tube and the valve, according to the direction of the current. This arrangement, though excellent in theory, has not proved of much practical value.

The transformer was found to suffer rapid deterioration, owing to the reflection of the Hertzian waves. The insulation of the end coils of the secondary soon broke down, rendering the coil useless.

Recently Messrs. Gaiffe have improved this arrangement by adding a protective system, which obviates this cause of accident. This has made the system of practical use, and we now consider it to be the ideal installation for alternating currents.

With *Dr. Brocq*, we showed this apparatus at the May meeting of the Société de Dermatologie, and we cannot do better than reproduce part of the communication : 'This new apparatus makes it possible to utilize an ordinary alternating current, without an interruptor, either for the production of X-rays or for high-frequency currents. Hitherto, if we wished to employ an alternating current, we had to use a Ruhmkorff coil—*i.e.* a transformer with an open magnetic circuit, supplied with a special form of interruptor. The choice of this lay between an electrolytic interruptor and the self-regulating interruptor of Villard, and it is well known how difficult it is to regulate either of these instruments.

It is true that a few years ago a transformer with closed magnetic circuit was made, and that this was used without an interruptor; but, though theoretically perfect, this apparatus rapidly deteriorated with use. M. Villard was the first to adopt this arrangement. The rapid breakdown of the end coils of the secondary was due to the reflected Hertzian waves.

To guard against these accidents we were obliged, even when working with high-frequency currents, to employ comparatively low tensions of 15,000 to 20,000 volts. The results obtained were not satisfactory, and even then the transformers broke down. With X-rays, where a higher tension is required, the apparatus soon became useless.

These transformers were soon abandoned, and the ordinary coils continued to be used. These are subject to the same dangers, but on account of their smaller output, they deteriorate more slowly.

Thus one of their greatest imperfections has added to their longevity.

The irregularities of the interruptor, of whatever form, render impossible even an approximate estimate of the output of the secondary. The great novelty in Gaiffe's apparatus is a protective arrangement, which has already been presented to the Académie des Sciences by *Dr. d'Arsonval.* This absolutely prevents the breakdown of the instrument by arresting the reflected Hertzian waves. It is composed of various condensers and resistances.

Their arrangement and magnitude are determined by considerations of the insulation of the coils of the primary, and the nature of the high-frequency waves which are required.

These improvements have been so successful that the installation

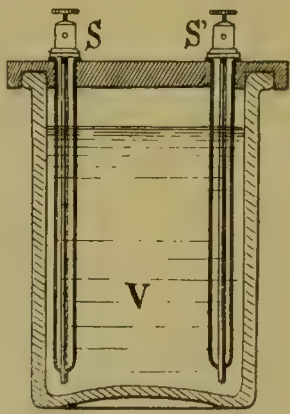


FIG. 5.—DETAILS OF LIQUID RESISTANCE.

can be employed for all forms of practical work—the condensing couch, the effleuve, resonance, bipolar radiations, or X-rays.

The apparatus consists of an ordinary transformer, with closed magnetic circuit, receiving an alternating current of 110 volts, which it converts into one of 60,000 volts.

The protective arrangement is threefold. Firstly, there is a series of condensers arranged between the poles of the secondary (Con., Fig. 6). Secondly, liquid resistances are introduced into the circuit, on either side of the transformer (Resist., Fig. 6). Finally, other condensers are introduced, between the liquid resistances and the tube (C., Fig. 6). These latter are the *d'Arsonval* high-frequency condensers.

They have the further advantage of insulating the operator, and

thus preventing any danger from his accidentally touching one of the poles. At the same time, they are a convenient method of limiting the current which passes through the tube.

The whole apparatus is enclosed in a glass-fronted cabinet, which

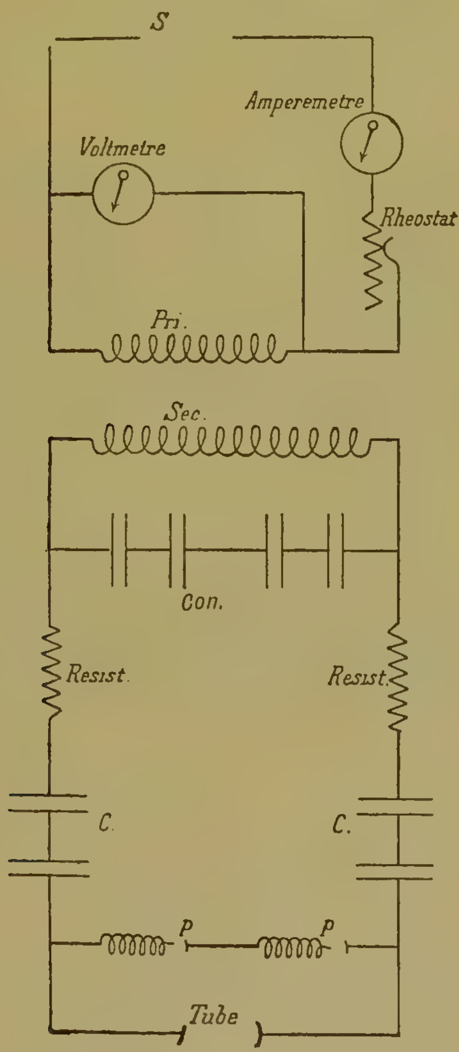


FIG. 6.—ARRANGEMENT OF THE TRANSFORMER.

obviates all danger of accident. The top is surmounted by a marble slab, to which are affixed the voltmeter and ampèremeter, for measuring the primary current, a rheostat resistance interposed in the primary current, and the terminals for the high-tension current.

The parts are so arranged that the apparatus may be used at will for high-frequency or X-rays by simply removing the Villard valves and interposing a spark-gap in their place.

This apparatus is free from danger and easily adjusted. The current may be regulated by merely moving the handle of the rheostat. It will give much greater power than any which can possibly be required at the present time. When the apparatus of

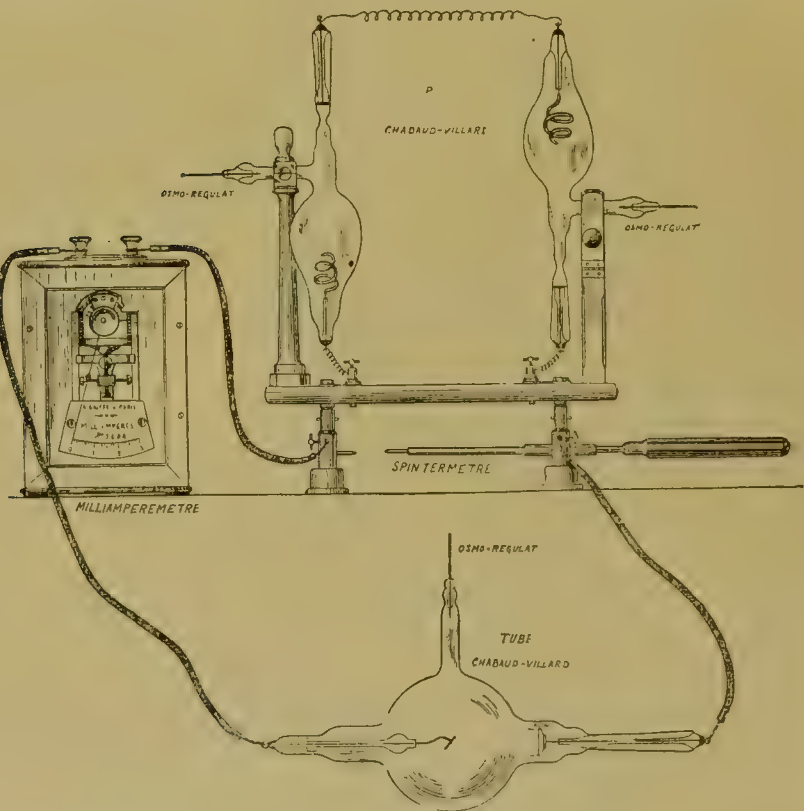


FIG. 7.—ARRANGEMENT OF VALVES, MILLIAMPÈREMETER, AND TUBE IN THE TRANSFORMER.

distribution has been perfected, and more power is required, it will only be necessary to increase the capacity of the condensers, which act as taps to regulate the output. The apparatus is, moreover, always ready for use; there is no trembler to get out of order, no mercury or petroleum to require constant renewal, and no noise to disturb the patient and wear out the nerves of the operator.

Let us now inquire how it is adjusted for producing X-rays.

The current should pass in one direction only. As the alternating current produced by this transformer changes its polarity with each oscillation, one series of waves must be absorbed before reaching the tube. For this purpose two Villard valves are inserted in parallel with the tube (P, P′, Fig. 6) in the manner indicated by *Villard* himself.

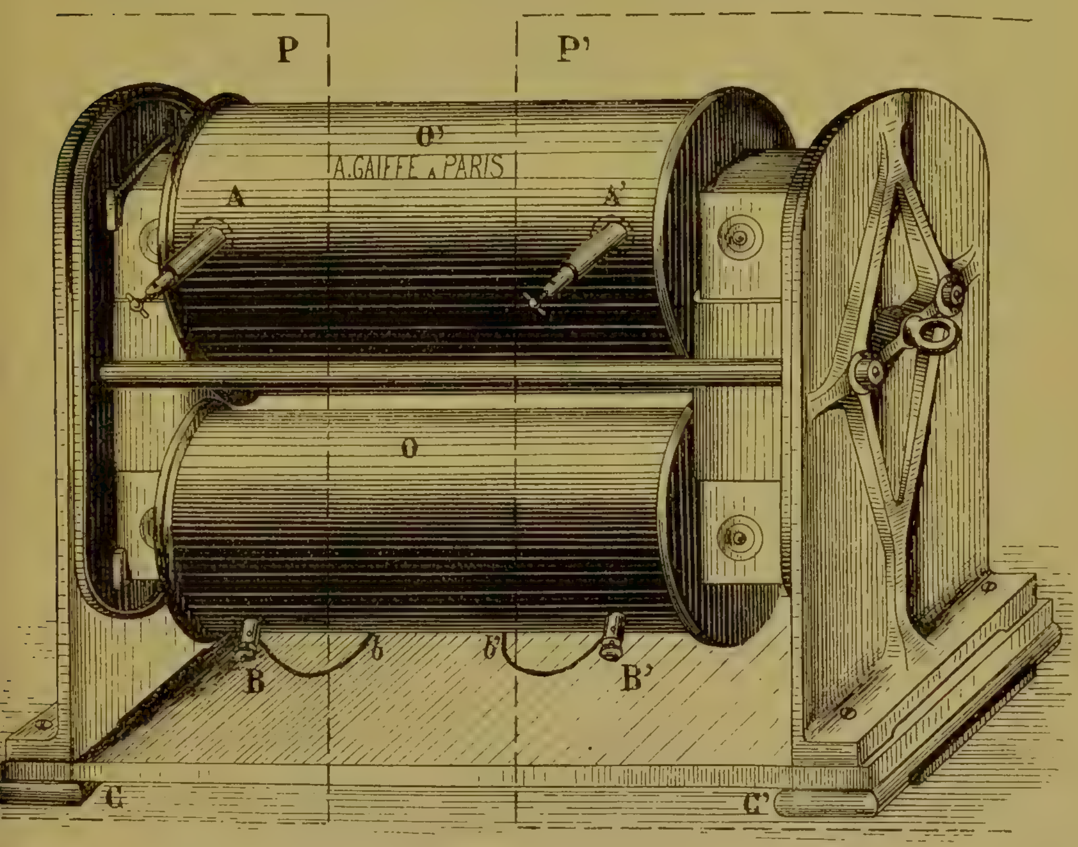


FIG. 8.—TRANSFORMER WITH CLOSED MAGNETIC CIRCUIT FOR HIGH VOLTAGE.

A, A′, Leads of the transformer ; B, B′, terminals of the primary ; O, O′, ebonite cylinders enclosing the coils ; P, P′, position of insulating sheets of mica.

The discharge through the Roentgen tube is perfectly regular, the fluorescent screen being as steadily illuminated as when a static machine is in use. The means for complete adjustment is afforded by the rheostat in the primary circuit.

There is theoretically no limit to the power which can be obtained by the use of this apparatus. As soon as the construction of the

tubes has been sufficiently improved, with a view to increasing the intensity of the rays, the length of exposure in radiography and the time of application in radiotherapy will be greatly decreased. At present the intensity of the X-rays obtainable is limited by the fear of injuring the tubes.

This installation may be arranged to obtain stereoscopic radioscopes. Two Roentgen tubes may be illuminated at the same time by using one of the two series of waves for each tube. An

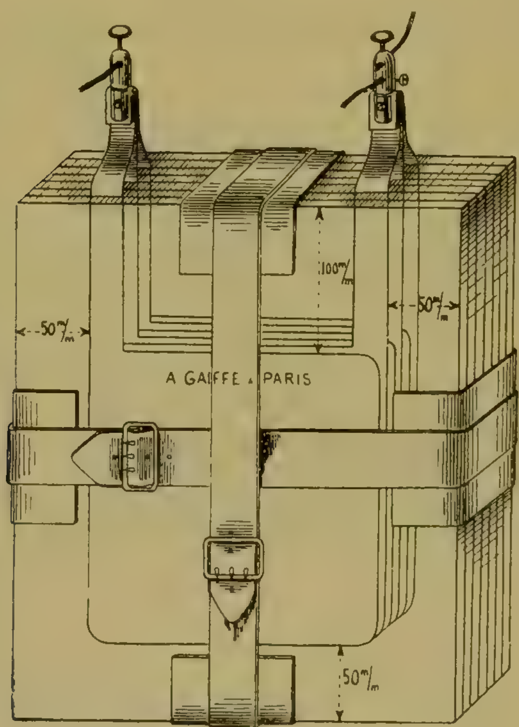


Fig. 9.—A Condenser.

automatic shutter, whose movement synchronizes with the interruptions of the current, is required. Such a shutter has been invented by Villard.

This apparatus may also be used with a continuous current. A commutator converts the continuous into an alternating current. By this means we get rid of the interruptor and the Ruhmkorff coil, both of them very imperfect and unsatisfactory instruments. The utilization of instruments for measurement is thus greatly facilitated. It may be objected to this form of installation that,

since it is supplied by the alternating current, it will be influenced by any variation in the mains. The only possible variations however are changes of potential and changes in the rate of alterna-

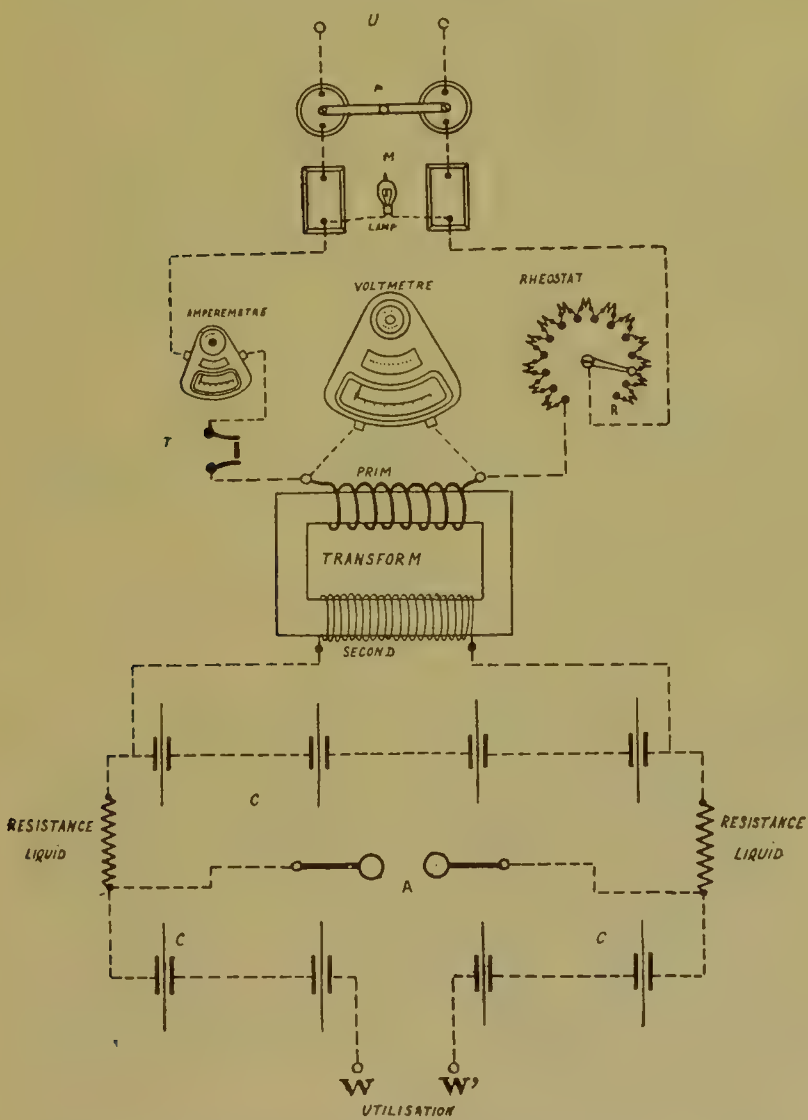


FIG. 10.—DIAGRAM OF THE INTERNAL ARRANGEMENT OF GAIFFE'S APPARATUS.

tion. Neither of these ever varies by more than 1 per cent., and their effect is therefore negligible. This is quite otherwise if ordinary current converters are used. These depend for their effect

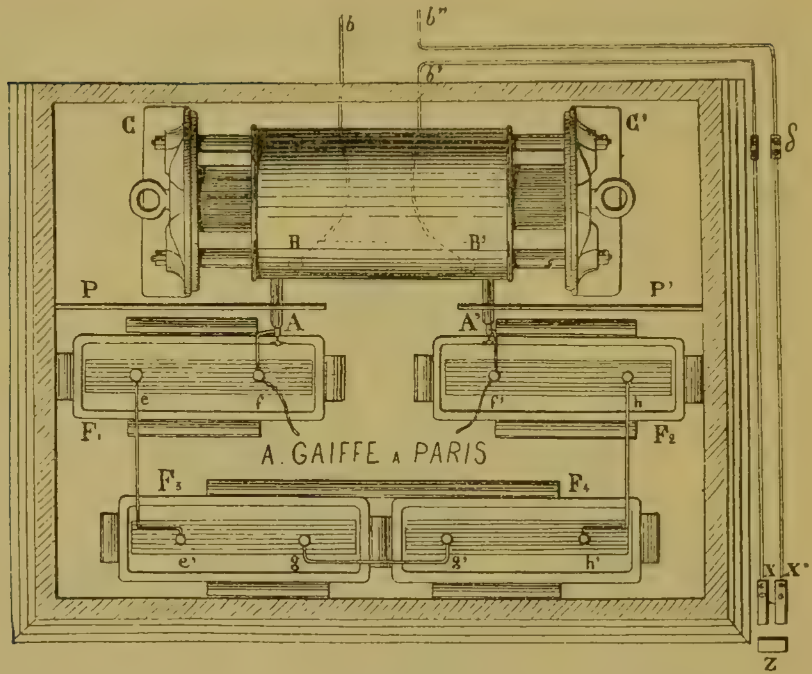


FIG. 11.—PLAN OF THE LOWER SHELF OF THE CABINET.
X X′, Springs ; Z, contact which is broken when the door is open.

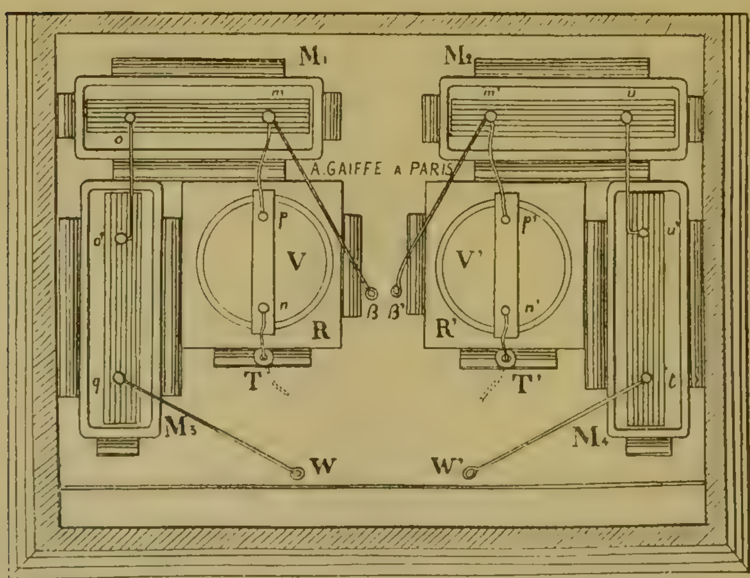


FIG. 12.—PLAN OF THE UPPER SHELF OF THE CABINET.
β, β', Wires leading to the spark-gap ; W, W′, terminals.

on synchronism with the current, and are therefore much more sensible to brief variations in the main.

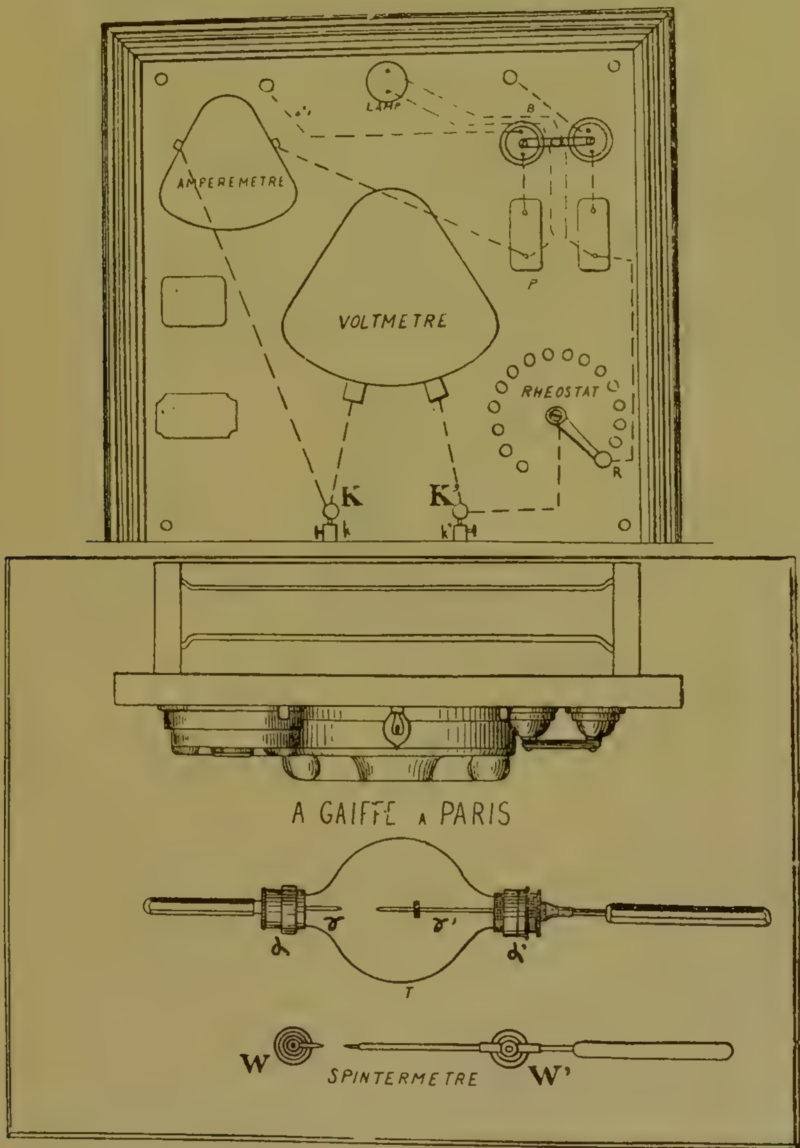


FIG. 13.—TOP OF THE CABINET, SHOWING MEASURING INSTRUMENTS, SAFETY RHEOSTAT, ETC.

This installation is equally adapted for high-frequency work. It is only necessary to remove the Villard valves and insert the spark-gap in order to adjust it for this purpose.

As we have already stated, the whole of the apparatus—transformer, regulators, condensers, and spark-gap—is arranged in a cabinet. Plate II. gives a general view of the arrangement.

Within the cabinet are the coils of the transformer, as shown in Fig. 9. These should never be used outside the case.

In Fig. 10 we give a general diagram of the installation, and Figs. 11 and 12 show the arrangement of the two shelves of the cabinet, with the connections of the transformer, condensers, resistances, etc.

Fig. 11 also shows the springs, X, X′, and the contact-plate, Z. The latter is attached to the door, and thus breaks the circuit whenever it is opened. All danger from electric shocks is thus

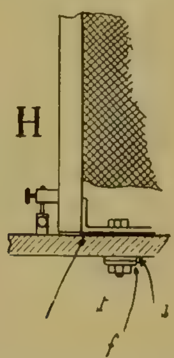


FIG. 14.—METHOD OF ATTACHING THE RHEOSTAT TO THE MARBLE SLAB.

obviated, since the apparatus cannot work unless the door is shut. All dangerous apparatus is thus out of the way of the operator.

The safety-fuses, measuring instruments, and regulating apparatus are attached to a marble slab on the top of the cabinet, as shown in Fig. 13.

This new installation of Messrs. Gaiffe seems to meet all theoretical requirements. We have had many opportunities of proving both its safety and its adaptability to practical conditions.

Nature of the Current produced by Coils and other Transformers.—The high-tension currents induced by a Ruhmkorff coil or transformer are not always in one direction. Firstly, a current is induced in the same direction as the inducing current, and then a second current in the opposite direction, in obedience to the ordinary law of magnetic induction. A conductor connecting the two terminals of the secondary is therefore traversed

by currents varying in direction every instant, and therefore without effect on a galvanometer. If however a sufficiently high resistance be introduced into the circuit, it is found that one current traverses the circuit more readily than the other. This is the 'break' current—*i.e.*, the one which travels in the same direction as the inducing current. If the resistance is sufficiently high, only the 'break' current will pass, and the inverse 'make' current may be almost entirely neglected. If there is a gap in the secondary circuit, the current will continue to pass, sparking across the gap. Experience shows us that the 'break' current sparks across the dielectric more easily than the 'make.' If now the gap be carefully increased, a position will be found in which only the 'break' current can spark across it. Such a spark-gap is said to filter the current, and the coil may then be said to possess a cathode and an anode.

A vacuum tube whose two electrodes present different surfaces to the spark produces an analogous effect. The passage of the 'make' current is obstructed. This is the principle of Villard's valve. The use of such a valve is not indispensable for the production of X-rays, but it protects the tube from the destructive action of the reverse current, and thus insures a longer life and a greater efficiency. No installation should be without a Villard valve, whether it be driven by a coil or a transformer.

Villard's Electric Valve.—The high-tension currents necessary to produce Roentgen rays can be obtained either from a static machine or from an induction-coil. In the latter case, we only require the direct or 'break' current. In order to preserve the efficiency of the tube, we must prevent the passage of the inverse or 'make' current. If the inverse current passes, both electrodes act alternately as an anticathode, with the result that a metallic deposit is formed on the inner surface of the glass, rapidly rendering it useless.

Béclère, in his article on the Villard valve, points out that the valve is specially useful in soft tubes of low resistance, such as are used in radiotherapy.

The only method of preventing the inverse current from spoiling the tube is to interpose a Villard valve. This instrument entirely prevents the passage of the inverse current.

The valve consists of a vacuum tube shaped like an elongated pear with a long stem. At either end is an aluminium electrode.

These differ both in shape and in their situation relative to the walls of the tube. One is very long, and wound into an open spiral, thus presenting a large surface; the other is short and straight, and has a comparatively small surface. The former occupies the swollen portion of the tube, and is consequently at some distance from the glass walls; the other, situated in the narrower neck of the tube, is on all sides close to the glass wall.

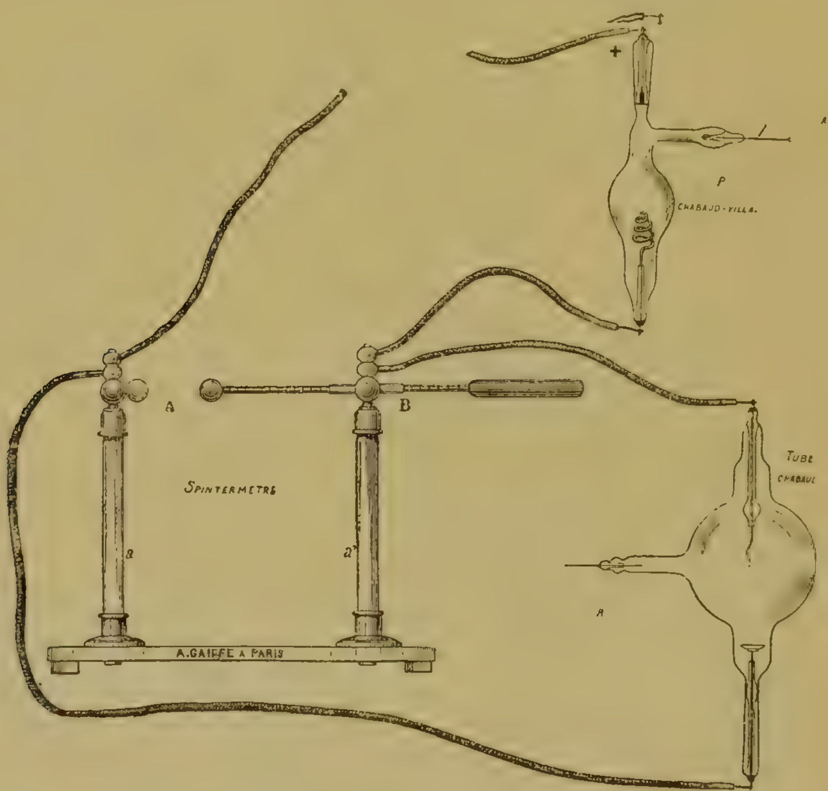


FIG. 15.—SPINTERMETER, WITH TUBE AND VALVE.

It is convenient to designate them as the spiral electrode and the straight electrode respectively.

M. Villard's investigations have shown that the passage of the electric current in a vacuum tube is caused by the flow of particles of gaseous matter towards the cathode, to take the place of those which have been shot out as cathode rays. It is, in fact, the cathodic afflux which determines the current. When the spiral electrode is the cathode, this cathodic afflux forms a widespread sheaf, offering but little resistance to the passage of the current.

If, on the other hand, the straight electrode is the cathode, the cathodic afflux is only a narrow thread, and the resistance of the tube is greatly increased. In the first case, the resistance, as measured by the spintermeter, is equal to a spark of from 2 to 3 millimetres in length; in the second case it is equivalent to a spark of some 10 centimetres.

The Villard valve is placed in series with a Roentgen tube in such a manner that its spiral electrode will act as cathode for the direct or 'break' current. It thus allows the 'break' current to pass freely, whilst completely stopping the inverse or 'make' current.

Like all other vacuum tubes traversed by a series of electric discharges, the resistance of the Villard valve gradually increases as the current passes. The inventor has therefore provided it with an osmo-regulator, similar to those used with the X-ray tubes. When the resistance of the valve becomes too high, it emits cathode rays, and the portion of the glass directly opposite the spiral of the large electrode becomes fluorescent. The degree of resistance may be estimated approximately by the changes in the brilliancy of the glow. To diminish this resistance, the little platinum tube of the osmo-regulator should be heated for a few seconds by a spirit lamp or an insulated gas-jet. By this means hydrogen is introduced into the bulb of the valve, the vacuum is decreased, and the resistance of the tube is diminished.

2. The Focus-Tube.

The essential part of the installation is the vacuum tube, which transforms the high-tension current into X-rays. This tube generally takes the form of a hermetically-closed glass globe, having platinum wires sealed into the extremities to serve as electrodes. The air is exhausted through a side tube, which is afterwards sealed with the blowpipe. The electrode connected to the negative pole of the coil is called the cathode. It emits the cathode rays in a direction normal to its surface. The electrode connected to the positive pole is termed the anode. The target which is placed in the path of the cathode rays is called the anticathode. When bombarded by the cathode rays, the anticathode gives rise to the Roentgen rays.

The early tubes were shaped like an elongated pear. At the

upper end an aluminium disc acts as cathode, the anode being formed of a platinum wire situated at the side of the tube. When the current passes, a portion of the tube opposite the cathode is illuminated by a fluorescent glow, thus giving rise to a certain quantity of Roentgen rays. In these tubes the glass wall itself acts as an anticathode. This has many disadvantages. The portion of the glass bombarded by the cathode rays is heated, gradually becomes porous, and finally melts.

At the present day the Roentgen rays are originated by allowing the cathode rays to bombard a metal screen or anticathode placed within the tube. This screen is usually made of platinum. The focus-tube is a further modification, in which the cathode rays, from a concave cathode, converge to a point at the anticathode. This important improvement is due to *Professor Thomson.*

Curious modifications have been made in the shape of the tube, and both the form and material of cathode and anode have been frequently varied. *Seguy* has constructed tubes with two positive poles, which he terms bi-anodic tubes. In his opinion this considerably increases the radiating power.

Finally, in order to prevent excessive heating and possible fusion of the anticathode when powerful coils are used, some modern tubes are furnished with an anticathode which may be cooled by the circulation of a stream of water. Attempts have also been made to protect the anticathode from the ill effects of heat by increasing its size.

These modifications are of small interest in radiotherapy, in which very large coils are seldom used.

At the present day a focus-tube has been evolved at once strong, simple, and elegant in form. The usual French type is the *Chabaud* tube, which will be described later; this, like all modern tubes, is provided with a metallic anticathode.

The next important point is the production of a high vacuum in the tube. This is effected by means of a mercury pump, attached to a side tube, which is afterwards sealed by the blowpipe.

If the focus-tube be put in action while still connected to the mercury pump, the following phenomena will be observed: At first, as the vacuum becomes more perfect, the intensity of the X-rays increases. This increase, however, soon reaches a maximum, which is followed by a rapid diminution of intensity in the rays, as the exhaustion proceeds. When an almost perfect vacuum

(*Hittorf's* vacuum) has been reached, the emission of X-rays ceases entirely. The exhaustion of a focus-tube must not therefore be allowed to proceed beyond a certain definite limit.

These phenomena are best explained by *Crookes'* bombardment theory. X-rays begin to be produced as soon as the process of exhaustion has proceeded far enough to render it possible for the cathode rays to reach the anticathode without being deviated by collision with the gaseous molecules remaining in the tube. As the rarefaction increases, there is an increase in the number of particles which are able to reach the anticathode, since the number of collisions is proportional to the total number of molecules present.

If the vacuum becomes still higher, the number of collisions will decrease, but the number of particles available to act as projectiles will also decrease. A point is thus reached where the diminution in the number of gaseous particles is no longer counterbalanced by the diminution in the number of collisions. The number of impacts on the anticathode will then begin to fall off, resulting in a diminution in the quantity of X-rays produced. *Crookes'* hypothesis is the only one that explains the variations in the production of Roentgen rays with alterations of the vacuum.

In practice it is not difficult to obtain the correct degree of vacuum in a focus-tube. New tubes therefore, as a rule, give excellent results. Unfortunately, this does not last, for the vacuum increases with use. A Crookes vacuum gradually becomes a Hittorf vacuum. Since the latter is a non-conductor of electricity, the resistance increases, and the production of X-rays falls off, and is finally arrested. Such a tube has become too 'hard' to conduct a current. *M. Gouy* has shown that this is due to the absorption of the residual gas by the anticathode, under the influence of the molecular bombardment.

Many methods have been devised for remedying this inconvenience. Theoretically, we might keep the tube permanently connected to the mercury pump, and thus alter the vacuum when required. This however would be impossible in practice.

The following are some of the methods used for attaining the same result: A substance is introduced into the tube which will give off a certain amount of gas under the action of heat. *Chabaud* uses a few fragments of caustic potash for this purpose. Before exhausting the tube, he replaces the air by carbon dioxide.

The potash absorbs a portion of this gas, and on gently warming, the potassium carbonate thus formed gives up the carbon dioxide

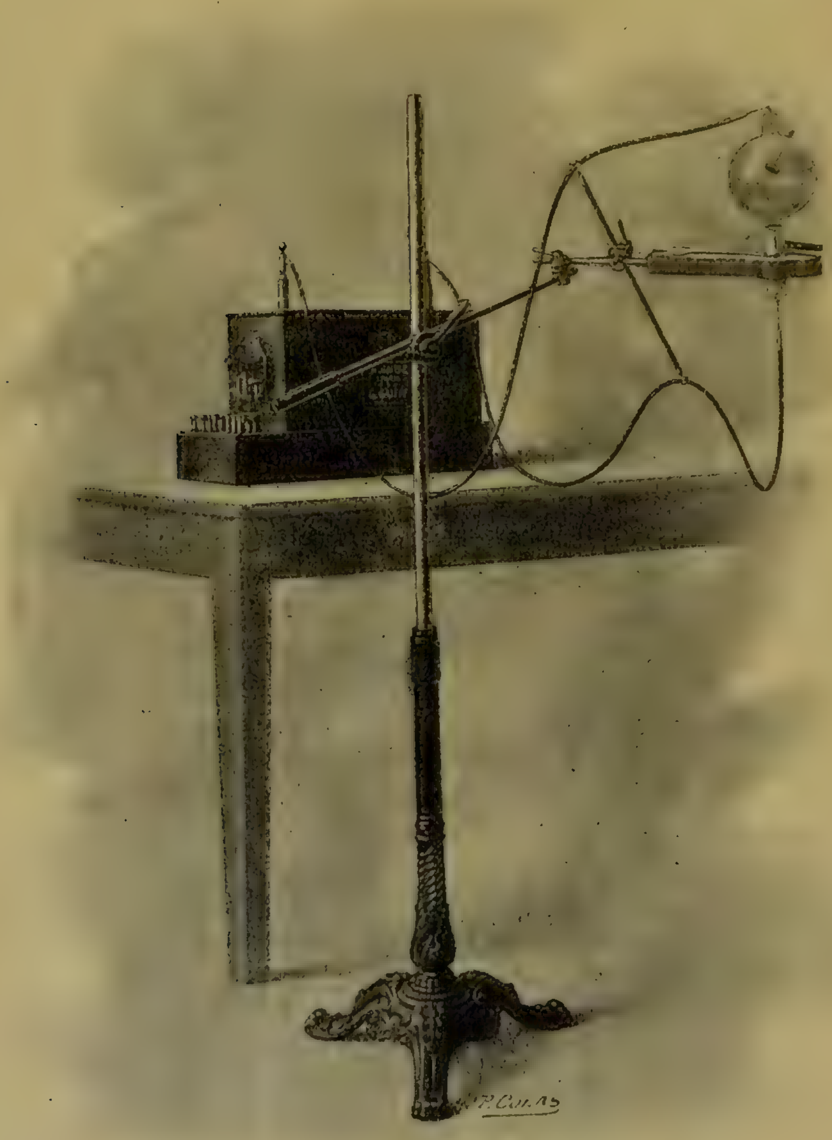


FIG. 16.—FOCUS-TUBE AND STAND.

again. Palladium, powdered charcoal, and many other bodies have been utilized in a similar manner.

Tubes supplied with some such contrivance are termed adjustable tubes, and are specially useful in radiotherapy. We will return to this subject in a future chapter.

Having obtained a suitable tube, we now join up the anode to the positive pole of an electric generator and its cathode to the negative pole, and thus obtain within the tube the beautiful greenish glow which is the sign of the production of X-rays.

If the connections are reversed, the tube will be badly illuminated. Circles of a bluish tint, alternating with darker zones, will appear, and the hemisphere opposite the anticathode will no longer be illuminated by a uniform greenish glow. In this case, to avoid damage to the tube, the current should be at once reversed by means of the commutator. If this cannot be done, the current must be cut off, and the two connections interchanged. The connecting wires, or 'leads,' should be covered with a thick protective layer of rubber, to secure complete insulation. If this precaution is neglected, there is a risk of a severe shock being conveyed to the patient, since in the course of a sitting these leads may come into contact with him.

3. Choice of an Installation.

The practitioner wishing to provide himself with a radiotherapeutic installation is often much embarrassed by the number of instruments offered for his choice. It may be useful to give some advice on this subject. We will begin with the simplest case, and perhaps the most difficult—that of a practitioner in the country or in a small town, where no public source of electricity is available. He may perhaps hope to work his coil by means of galvanic cells, but he will be bitterly disappointed, and the cells will be a constant source of annoyance to him. They are not a practical means of supply, since they require constant recharging, and are moreover, very expensive to keep up. Accumulators are out of the question, since, being at a distance from any large electrical plant, he will be unable to get them recharged. Under these conditions, there is but one solution: he should provide himself with a small six-plate static machine by a good maker. If necessary, it may be a portable one, which will enable him to take it to the patient's bedside if he cannot be moved.

A static machine should be located in a well-ventilated room, free from damp, and not too near the wall. Every morning it

should be carefully dusted with a well-dried cloth, and from time to time it should be thoroughly cleaned. How is it to be driven? The simplest and easiest method is by hand. If this is found too fatiguing, a small petrol motor may be used. If expense is no object, a complete electric plant may be set up, and a small dynamo used to charge a battery of accumulators, from which the Ruhmkorff coil may be driven direct; or it may be driven with the intervention of a motor. With this installation a source of electric energy is available which can also be utilized in various other ways.

Practitioners in the larger towns are in a much more favourable position. With a public electric service for lighting, the company is always ready to supply the current for other purposes. In some of the smaller towns however it may happen that the current is only available in the evening, after four or five o'clock. In this case, unless he is content to do all his electric work at night, the practitioner is not in any better position than his colleague in the country. There is one expedient however: he may use a battery of accumulators, recharging them every evening. This may be done direct from the main if the current is continuous, or by means of a commutator if the current is an alternating one. With a little supervision, this recharging may safely be left to a servant when necessary. If however, there should happen to be an electric plant for industrial purposes in the neighbourhood, two sets of accumulators may be employed, allowing one set to be recharged there while the other is in use.

Finally, in towns where the electric current is available at all hours, any variety of machine may be used at will. With a continuous current the Ruhmkorff coil is undoubtedly the best. It gives excellent results with minimum expense. If the installation is required for radioscopy as well as for radiotherapy, a static machine of ten or twelve plates is preferable. It gives greater power, and insures a perfectly equable illumination. It is however more expensive than the coil, and needs more careful handling.

We may also use Gaiffe's new transformer with closed magnetic circuit, which does not require an interruptor. The continuous current must then be changed into an alternating one by means of a commutator.

When the current at our disposal is an alternating one, the Ruhmkorff coil may still be used, but its use will cause endless annoyance. The alternating current may be changed to a con-

tinuous one by means of a transformer, but this is not a very practical method. A specialized form of interruptor, such as Wehnelt's or Villard's, may be used. These allow only one phase of the alternating current to reach the coil. Neither of these instruments is very satisfactory. Wehnelt's interruptor is irregular in its action, is very inconvenient, and often causes injury to the coils or tube, and Villard's interruptor gets out of order very easily. With alternating currents it is therefore preferable to employ a static machine driven by a small motor.

Quite recently however a theoretically perfect apparatus has been constructed, which enables us to use a current without the interposition of an interruptor. This is Gaiffe's transformer, which in our opinion fulfils all that is claimed for it. Its only drawback is its comparatively high price. With this compact and elegant machine, better results may be obtained with an alternating current than any we have met with hitherto, even with a constant current. Thanks to subsidiary apparatus and additional instruments of measurement, we can always be certain of a constant result in the technical application of the rays. We may also use this apparatus for high-frequency currents.

Some investigators assert that the pathogenetic effects of the X-rays vary with the source of the high-tension current which produces them. Others consider that untoward accidents do not occur when a static machine is used.

In January, 1904, *Gastou* stated at a meeting of the Société de Dermatologie that he had obtained successful results with a static machine, whereas he had often failed when an induction-coil was used for the production of X-rays.

In July, 1904, *Ch. Monod* and *Bouchet* reported a case of epithelioma cured by radiotherapy. They say: 'Contrary to what has recently been stated, we hold that the static machine, though perhaps slightly less dangerous, is yet capable of producing severe radiodermatitis. The danger of such an accident is increased with the number of plates employed, and becomes almost inevitable when twelve, sixteen, and twenty-plate machines are used.'

It is very necessary that this erroneous idea should be corrected. The only important factor in radiotherapy is the quantity and quality of the X-rays themselves; the character of their source is quite immaterial. This was conclusively shown by *W. B. Snow*

of New York, and *R. J. Nunn* of Savannah, at the Twelfth Annual Congress of the American Electro-Therapeutic Association. We might just as logically attempt to establish a difference in the effect produced by ten-horse power supplied by a steam-engine, and the same power obtained from an electro-motor, or to distinguish between the illuminating power of two twenty-candle-power electric lights, one supplied by a direct and the other by an alternating current. We will not enter further into a consideration of *Monod* and *Bouchet's* condemnation of the twelve-plate static machine.

The therapeutic reaction depends on the quantity of X-rays absorbed by the skin; this in its turn depends not only on the number of plates of the machine, but on the rapidity of rotation, the material of the plates, and the nature of the focus-tube. Of course, a twelve-plate machine, under the same conditions, will cause the emission of more X-rays in a given time than a six-plate machine.

It is inadmissible, however, to say that the stronger machines must necessarily cause more dermatitis.

CHAPTER III

METHODS OF EXACT MEASUREMENT IN RADIOTHERAPY

With apparatus such as we have described, it is possible to practise radiography, since it is easy to obtain X-rays in variable and uncertain quantities. It would be wholly impossible, however, to practise radiotherapy—*i.e.*, the application of X-rays to medical treatment—in a scientific manner and without danger to the patient. For this purpose we need in addition, instruments of precision capable of measuring the X-rays themselves and the output of the apparatus which produces them. We proceed to describe the various instruments of measurement, reserving the consideration of the methods of application for the second part of this book.

We shall borrow largely from the work of *Dr. Béclère*, an acknowledged master of the arts of radioscopy, radiography, and radiotherapy.

1. *Regulating-Tubes.*

A most important desideratum in radiotherapy is the maintenance of a constant vacuum in the interior of the Roentgen tube. As is well known, the same tube will produce a whole series of X-rays of different degrees of penetration, according to the rarefaction of the air within it.

The higher the vacuum, the greater is the resistance in the interior of the tube, and the less the quantity of X-rays produced. The higher the vacuum, the greater is the penetration of the X-rays—*i.e.*, they pass more readily through the tissues without affecting them in any considerable degree. These penetrating rays do not give a black shadow of the bones on the fluorescing screen.

A focus-tube does not remain *in statu quo* after it has been worked for some time. The vacuum has a tendency to become higher, the penetration of the rays gradually increases, and their action on the tissues diminishes. This process continues till the vacuum becomes so high that the current can no longer pass, and the tube becomes useless. Although it is hermetically sealed, it appears as if a portion of the residual gas had been removed from the tube. This is in fact the case, for under the influence of the electric current some of this residual gas has been absorbed by the electrodes.

We have already described various arrangements designed to obviate this rise of the vacuum, none of which however are of any great practical utility.

For a tube to be really a 'regulating-tube,' it should have a means of increasing or decreasing the vacuum at will.

The Chabaud Focus-Tube with Villard's Osmo-Regulator.—Of all vacuum regulators, Villard's osmo-regulator is the best, the most ingenious, and the simplest. It enables us to vary the vacuum easily and rapidly, and thereby to augment or diminish the number and penetration of the X-rays produced. In France it is usually attached to the Chabaud focus-tube.

Many years ago *Troost* and *Sainte-Claire-Deville* studied the action of platinum under the influence of heat. They found that when raised to a red heat this metal became permeable to hydrogen. This is the principle of the osmo-regulator of Villard. It consists of a simple tube of platinum, which is closed at one end, the other extremity being sealed into the wall of the focus-tube. If now the platinum tube be raised to a red heat in a flame of gas or alcohol, it is rendered porous, and the hydrogen always present in the flame, will enter the focus-tube. On allowing the platinum tube to cool, it becomes once more impermeable, and the hydrogen is unable to escape from the tube. The same principle enables us to increase the vacuum. The platinum tube is heated, but without allowing it to come in contact with the flame. For this purpose the tube is protected by a platinum sleeve, within which the air circulates freely. This outer sleeve is raised to a red heat by means of a spirit lamp or a gas-jet, care being taken not to allow the flame to reach the interior of the sleeve. The platinum tube in this case is surrounded by heated air only, and the hydrogen in the focus-tube passes outwards through the porous platinum.

These two operations may be repeated again and again, even while the focus-tube is at work. The gas-jet in this case must be carefully insulated from metallic contact with the operator. By the use of this contrivance we are enabled to alter the vacuum

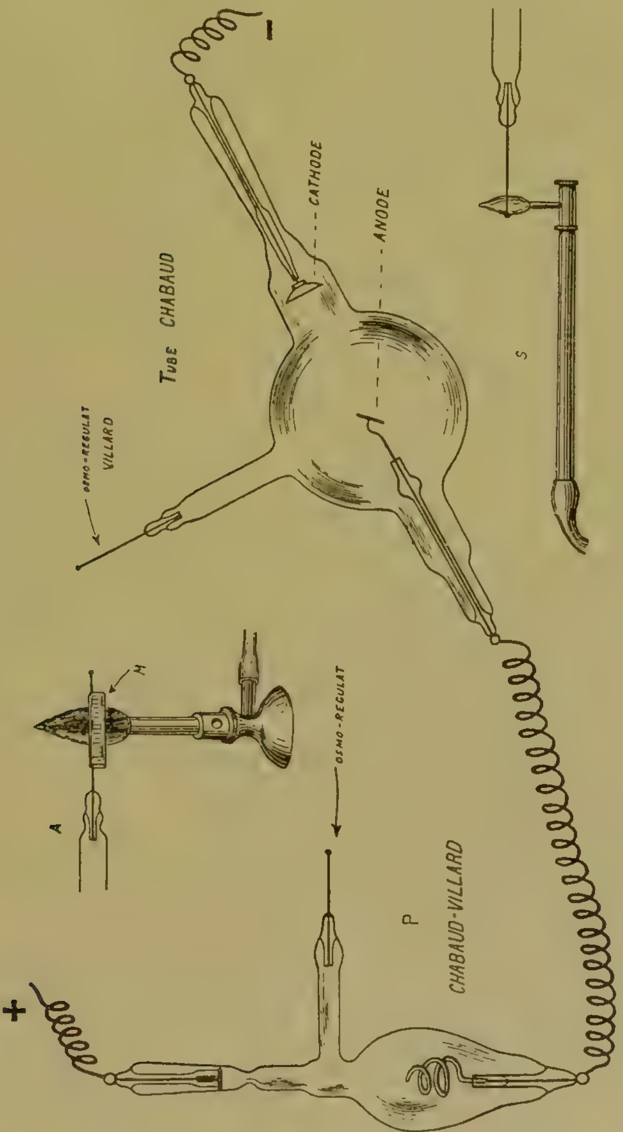


FIG. 17.—VILLARD VALVE, FOCUS-TUBE, AND OSMO-REGULATOR. (A. GAIFFE.)

in a focus-tube, and thus vary the penetration of the X-rays produced.

Such regulating-tubes have a life of indefinite length, since the vacuum never rises so high as to prevent the passage of a current.

This advantage compensates in some measure for the high price charged for these tubes.

In the course of his lectures *Dr. Béclère* shows a simple contrivance to demonstrate the action of this regulator.

It is composed of an exhausted V-shaped tube, each limb of which is again bent outwards at right angles. The angle of the V is filled with mercury, and an osmo-regulator is sealed into the end of one limb. If this is raised to a red heat, hydrogen passes into the interior, the pressure is increased, and the mercury falls in this limb of the V tube, rising to a corresponding degree on the other side. On removing the source of heat this action ceases. If now the platinum sleeve is placed in a position to protect the regulator tube, and the sleeve is heated with due precautions, the hydrogen leaves the interior of the tube; the mercury rises in this branch of the V and falls on the opposite side.

Drisler's Focus-Tube.—*Drisler* has constructed a focus-tube with two anodes. This is regulated by the passage of an electric spark. A little reservoir is attached to the side of the tube, and this contains the regenerating material. If the vacuum becomes too high, a current is passed through this side tube. The spark heats the regenerating material, and the resistance of the focus-tube is decreased. The current is led to the subsidiary reservoir by a special metallic wire provided with an insulating handle.

We have not ourselves tried it, and therefore can say nothing as to its merits. It has, however, one disadvantage. It is only designed to diminish the vacuum, and is not capable of increasing it, as may be done with the osmo-regulator. Moreover, when the focus-tube is in action it will naturally become hot, thus heating the material in the reservoir, and causing an undesigned decrease of the vacuum.

With this mode of regeneration the focus-tube retains the initial amount of gas, although this becomes distributed in a different manner. The gas driven off from the regenerating material has been in the focus-tube from the time it was made and sealed. On the other hand, the osmo-regulator introduces hydrogen from without, thus varying the total quantity of gas in the interior of the tube. This does not occur with any other system of regulation.

Müller's Regulating Focus-Tube.—*Müller's* tube is similar to the preceding. A small reservoir is attached, which

is furnished with a separate anode and cathode. On passing a current through this the electrodes become heated, and gas is evolved, causing a corresponding decrease of the vacuum. A special arrangement is used to obtain an automatic adjustment of the resistance during the action of the tube. It is doubtful, however, whether these results are always obtained in practice.

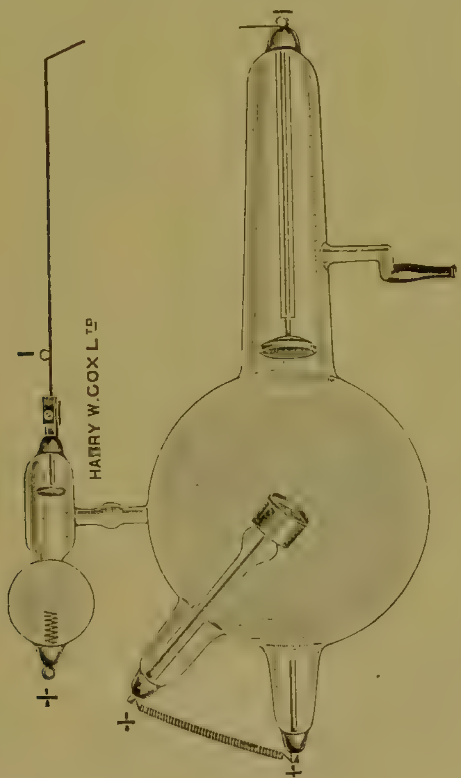


FIG. 18.—MÜLLER'S FOCUS-TUBE.

This tube can, it is said, be hardened by connecting the positive lead to the spiral contained in the supplementary reservoir.

Müller of Hamburg also makes a large tube, the cathode of which is cooled by means of water circulation. With this a current of 5 milliampères can readily be obtained in the tube.

Lœvenstein of Berlin makes a tube with a somewhat similar system of regulation. All of these tubes work well, but their regulation is not nearly as perfect as that of the osmo-regulator, which is much to be preferred, especially in radiotherapy.

2. *The Spintermeter.*

With the apparatus described above we can regulate the penetration of the rays. In order, however, to get the full value of this power of regulation we should be able to measure the penetration at any given moment; or, what is the same thing, to measure the degree of vacuum in the tube. With a given focus-tube and coil there is a constant relation between the resistance of the tube and the penetration of the rays. The greater the resistance of the tube, the greater the penetration of the rays. The only method of deciding whether the rays are as penetrating to-day as they were yesterday is to compare the electric resistance of the tube on the two occasions. By means of an osmo-regulator we are able to adjust a tube so as to give off rays of the same degree of penetration as on a previous occasion—it may be days or weeks before. How may the electric resistance of a focus-tube be measured? While the tube is at work we may bring the electrophores—*i.e.*, the wires which lead from the coil to the tube—gradually nearer to one another until a spark passes, thus short-circuiting the current. Like all other forces, electricity tends to take the easiest path, to pass where it finds least resistance. The spark between the two wires appears at the precise moment when the layer of air between them offers a less resistance than that of the focus-tube. If the tube-resistance is great, the spark is a long one, and appears when the wires are some distance apart; if the resistance of the tube is small, the spark is short, and appears only after the wires have been brought very near together. Thus, if the leads are brought gradually nearer and nearer to one another, the length of the spark between them will be an exact measure of the resistance of the tube. The spark is said to be the equivalent of the tube-resistance, and the operation is called 'the determination of the spark-equivalent of the tube.' If, for example, a tube is said to have a spark-equivalent of 3 inches, it means that the electric resistance of the tube is equal to the resistance of a layer of air 3 inches thick. In order to facilitate the measurement of the equivalent spark, *Dr. Béclère* has invented an instrument, which has been constructed by M. Drault. This instrument, which he has named the spintermeter, or spark-measure, is an indispensable adjunct to all radiotherapeutic apparatus. It consists essentially of a graduated metallic rod, terminated by a ball at

one end, and by an insulating handle at the other, working smoothly in a metallic tube mounted on an insulating support. The ball may thus be adjusted at a greater or less distance from a similar metallic ball, mounted on a second insulating pillar at a distance of some 10 inches from the first. The whole is supported on a wooden base.

The insulated ball is attached to one lead and the adjustable ball to the other lead, each being joined to a pole of the coil or static machine which supplies the focus-tube.

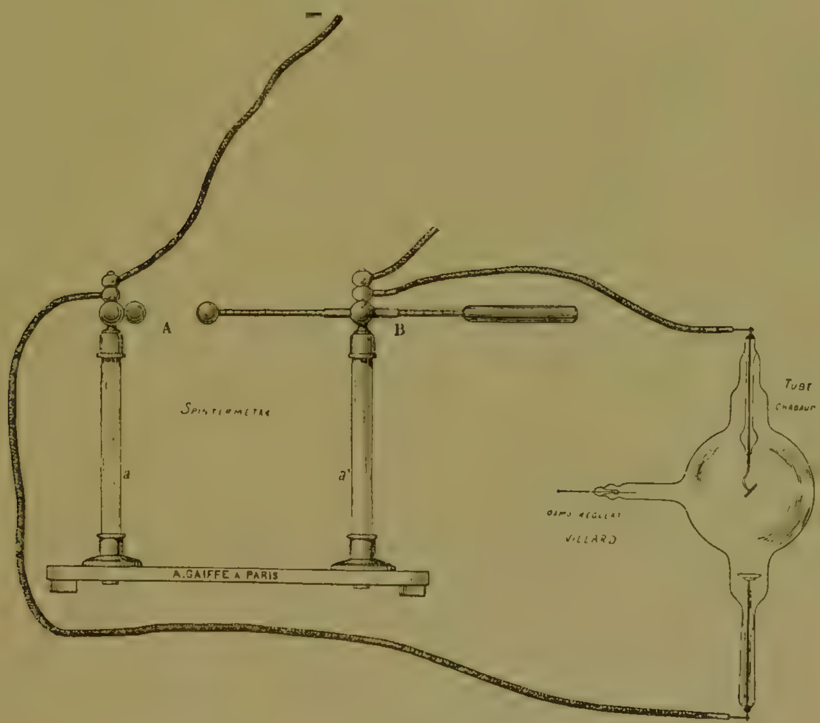


FIG. 19.—SPINTERMETER AND FOCUS-TUBE.

The spintermeter is thus placed in the circuit which drives the focus-tube in parallel with the tube. If the two balls are near enough, a spark passes between them when the current is turned on. The adjustable ball is then gradually drawn back until the sparking becomes intermittent. The length of the spark-gap may then be read off on the graduated rod. This measurement of the 'equivalent spark' enables us to determine the resistance between the electrodes of the focus-tube. If this resistance is not the one required, it may be increased or diminished by means of the osmo-

regulator. In order to maintain any desired resistance during exposure, we proceed in the following manner: The balls are separated just so far as to prevent the passage of a spark, and the gas-jet is held in readiness to heat the osmo-regulator the moment the occurrence of a spark shows that the resistance is becoming too high.

The length of the equivalent spark varies with the shape of the poles of the spintermeter. If we place three spintermeters in parallel in the same circuit, the first having pointed terminals, the second spheres of 1 centimetre diameter, and the third spheres of $2\frac{1}{2}$ centimetres, we shall have for the same resistance three equivalent spark-gaps, the length of which increases with the size of the terminals. For the same instrument the length of the spark-gap is always proportional to the resistance of the tube.

Thus the spintermeter, by measuring the length of spark-gap equivalent to the resistance of the focus-tube, gives us an indirect indication of the penetration of the rays issuing at any moment from a Roentgen tube.

This mode of measurement was adopted in England as long ago as 1901. At a discussion in the Roentgen Society, in April, 1901, on X-ray dermatitis, allusion was frequently made to 'the parallel spark.'

Scholtz made use of the spintermeter in his remarkable experiments on the action of X-rays on the skin in health and disease.

In conclusion, we consider this instrument absolutely indispensable to any installation devoted to radiotherapeutic purposes.

3. *Radiochromometer.*

The spintermeter enables us to measure accurately the resistance of a focus-tube, but it gives a very imperfect estimate of the penetration of the rays emitted.

This is shown by an experiment due to *Dr. Margaret Sharpe.* Two tubes were used, driven by the same electric generator and with the same spark-gap. Although both were placed at the same distance, only one of these produced an inflammatory reaction of the skin. The difference was clearly due to a difference in the construction of the tubes themselves, which were in fact manufactured by different makers.

Two focus-tubes may differ in many respects. They may be of unequal size, the electrodes may be nearer or further apart, their

shape may differ, and the materials used in their construction may vary. It must be remembered that the spark-gap gives the total resistance of the tube. Of this a portion only—viz., that between the electrodes—determines the quality of the rays emitted by the tube. How, then, is it possible to estimate the difference of two tubes as regards the nature and quality of their radiations?

A contrivance due to *Benoist* enables us to answer this question.

By its means the different radiations issuing from an X-ray tube may be arranged in the order of their penetration power, just as easily as the solar radiations may be separated according to their refrangibility. The radiochromometer enables us to determine with rapidity and precision the penetration power of the X-rays given off by a focus-tube at any moment.

This instrument is the result of *Benoist's* experiments on the transparency of matter to the Roentgen ray. It gives us a practical means of classifying with precision the X-rays and other similar radiations.

It has long been known that there are several kinds of X-rays characterized by their unequal power of penetrating more or less opaque bodies, such as flesh or bones, just as the coloured rays composing ordinary light pass with greater or less facility through a red or a blue glass. *Benoist* has given to this property the name of radiochrœism.

Just as the photographer must know whether the light in his studio is blue or red, so must the radiographer be able to recognise the character of the rays he is using.

Hitherto the only method of doing this has been by watching the general appearance of the light in the focus-tube, measuring its resistance by the spintermeter, or observing the contrast of shadows of bone and muscle on the screen. A somewhat vague classification of X-rays into 'soft' or slightly penetrating and 'hard' or very penetrating rays was thus obtained.

The radiochromometer enables us to attach to each variety of ray a precise numerical designation, which does not vary from time to time, and is independent of the personal equation of the observer.

It is founded on the following principle: Given two bodies, such as aluminium and silver, of different atomic weights, and therefore of unequal transparency to the X-rays, the ratio between the

transparencies of these two bodies will vary with the penetrating power of the rays. Taking arbitrary numbers: supposing aluminium is five times as transparent as silver for soft X-rays, it will be ten times, twenty times, thirty times as transparent for rays of greater degrees of hardness.

Benoist chose aluminium and silver for the materials of his apparatus for this reason. The transparency of silver varies but little with an increase in the hardness of the rays, whereas the transparency of aluminium increases greatly as we ascend the scale of penetration power.

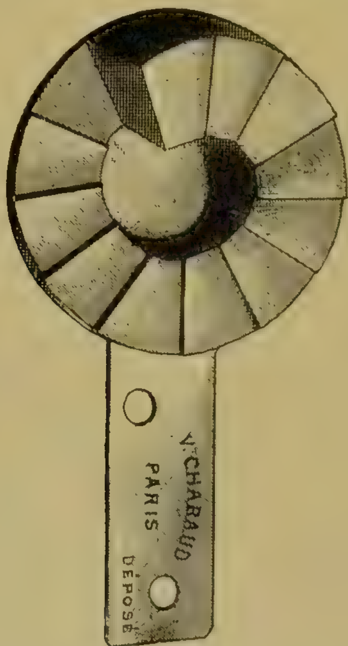


FIG. 20.—RADIOCHROMOMETER OF BENOIST

The radiochromometer is formed of a disc of aluminium, divided into twelve sectors, whose thickness varies from 1 to 12 millimetres. The aluminium disc is pierced by a central aperture, in which is placed a plate of silver 0·11 millimetre in thickness. The sectors are arranged like the figures on a clock-face, thus enabling any one of them to be easily recognised by its position. No. 1 is in the position corresponding to one o'clock, No. 12 corresponding to that of twelve o'clock.

The apparatus is used either in front of a fluorescent screen or above a photographic plate. In either case one of the sectors will

match the tint of the central disc; the number of this sector will indicate the radiochromometric intensity of the X-rays employed. This number will suffice to define the quality of the rays in question.

For instance, in Fig. 21 it is found that the seventh sector of aluminium has the same depth of shade as the central disc. The X-rays employed are defined by saying that they mark seven degrees on the radiochromometer, or that they are of the seventh degree of hardness.

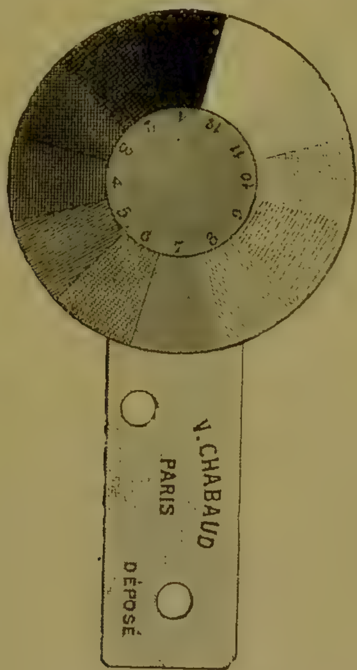


FIG. 21.—BACK VIEW OF RADIOGRAPH OF RADIOCHROMOMETER.
On the screen the figures will be reversed—*i.e.*, the sectors will be numbered clockwise.

In this manner we obtain a scale of 12 degrees, which includes all the variations of penetration hitherto used. Medium rays are expressed by the figures 5 or 6, very hard rays by 9 or 10, and very soft rays by 2 or 3. The average rays emitted by radium correspond to ·5 of this scale.

One can easily estimate, if required, a quarter or a half degree on the scale: for example, suppose the central disc is brighter than the second sector, and darker than the third: if the tint is equidistant between the two sectors, we read 2·5; but if it is more nearly that of the second sector, we read 2·25.

A diaphragm of blackened cardboard may be used, in order to isolate each sector at will, and thus render the comparison more easy. When the fluorescent screen is used this diaphragm is made of lead.

A radiochromometric telescope has been designed to enable us to observe the focus-tube during action. It consists of a thick copper telescopic tube, provided with a shield, which fits closely over the eye, and excludes all external light. The other extremity carries the radiochromometer, in contact with which is a fluorescent screen. A rotating diaphragm enables us to examine each sector successively. This instrument is pointed at the anticathode, and the sector is selected which best matches the central disc. The number of this sector will give the radiochromometric power of the rays. With a little practice the comparison is easily made, either with a fluorescent screen or with a photographic plate. This instrument has given a precision to the use of the rays similar to that which the thermometer has conferred upon medicine.

We may now determine for any given tube the ampèrage and the spark-gap needed to produce rays of any recognised degree of penetration.

For instance, using the same coil and interruptor, with the same voltage and current in the primary, a given tube will emit rays of penetration No. 2 when the spark-gap is 2 centimetres in length; it will give out rays of penetration No. 6 when the spark-gap has increased to 10 centimetres; and so on for other degrees of exhaustion.

It is self-evident, then, that the same adjustment of the coil does not necessarily give rise to rays of the same quality of penetration from two different focus-tubes. As we are led to expect from the laws of transparency, of emission and of absorption, as described by *Benoist*, there are very great differences in the behaviour of different tubes in this respect. Thus an aluminium anticathode will give rays of 4·5 degrees of penetration, whilst a platinum anticathode, for the same primary current, will emit radiations of 6 degrees.

At all events, we may rest assured that, with a given focus-tube, coupled to the same spintermeter, with a constant voltage and ampèrage and the same frequency of interruption, we shall always obtain the same degree of hardness as measured by the radio-

chromometer, whether the experiment be repeated the next day or the next month.

It is more especially in radiotherapy that we need to employ rays of a known and constant penetration. The radiochromometer is therefore one of the most important instruments in an installation for radiotherapy.

We must remember however, that the degree of penetration measured by this instrument is that of the most penetrating rays given off by the tube at the moment of measurement. The radiations emanating at any moment from the focus-tube are of very varied quality, and not all of the same penetrating power. The radiochromometer registers only the most intense of these, and takes no notice of the softer rays accompanying them. It measures the maximum, not the minimum, penetration. This is however, of only theoretical importance, and does not diminish the practical utility of the apparatus.

More recently *Benoist* has constructed a new model, marking half degrees, each plate of aluminium being only half a millimetre in thickness.

4. *The Chromoradiometer.*

With the instruments we have already described, we can vary the vacuum in the focus-tube and gauge the degree of penetration of the issuing rays.

We are still however ignorant of one factor—viz., the quantity of X-rays which are absorbed by the surface exposed to their action.

This factor is a most important one in the practice of radiotherapy, for as we shall see later on, the reaction of the skin depends on the number of X-rays absorbed by it.

It was not till 1892 that any attempt was made to determine this factor. At the second International Congress of Electrology and Radiology *Dr. Guido Holzknecht* presented an instrument of his own invention, which he called the chromoradiometer.

The invention is based on the law established by *Kienböck*, that 'the degree of reaction depends on the quantity of X-rays absorbed by the skin.' The instrument measures this quantity, or at all events the quantity which falls on the exposed surface.

A photographer desirous of attaining a certain predetermined exposure, employs a sensitized paper slip, which is blackened by

the action of light. He stops his exposure when this test-paper has attained a certain tint, corresponding to one of a series in a standard scale. In like manner *Holzknecht* uses a substance which is coloured by the X-rays. He places this on the skin and measures the quantity of rays absorbed, by the degree of discoloration obtained. He is thus able to stop the exposure when the predetermined quantity of X-rays has been absorbed.

Before describing this apparatus in detail, it will be interesting to note the means by which *Kienböck* was led to his discovery.

Goldstein, in a series of experiments reported to the Academy of Sciences of Berlin, showed that certain salts are coloured by the cathode rays. This reaction may occur at ordinary temperatures or only on heating. Chloride of sodium, for instance, is coloured brown and chloride of potassium violet.

Other substances become strongly heated when they are irradiated, and give rise to various colour reactions. Chloride of lithium becomes a greenish yellow, and carbonate of potassium turns a heliotrope colour.

On exposure to the air or to a high temperature, all of these colours speedily disappear. It is a moot question whether the coloration is due to a chemical change or to an allotropic modification.

Later on *Goldstein* showed that this property of coloration was possessed not only by cathode rays, but by ultra-violet light.

Moreover, he brought forward the hypothesis that cathode rays, X-rays, and Becquerel rays have this important property in common—they are all transformed into ultra-violet rays at the point of impact with the surface. To this property he ascribed all the effects due to their absorption. In support of this hypothesis, he adduced the fact that the results of the absorption of these four varieties of rays were absolutely identical.

Holzknecht pointed out that, if this theory were correct, the secondary colorations discovered by *Goldstein* should be produced not only by cathode rays, but by the Roentgen rays.

Experiment confirmed *Holzknecht's* hypothesis. He proved that the X-rays produced the same colorations as did the cathode rays—a fact which had been already demonstrated by *Villard* in France.

There is one point of difference, however. The cathode rays colour merely the exterior of the crystals, since they only pene-

trate one or two hundredths of a millimetre below the surface; the Roentgen rays, on the other hand, traverse the whole thickness of the crystal, and colour its entire mass. It was found that for a definite thickness of one of these salts the intensity of the coloration is proportional to the quantity of rays absorbed.

Pursuing his studies on this subject, *Holzknecht* discovered that certain salts, after fusion together and subsequent cooling, are coloured in a different manner from a mixture of the same salts in powder.

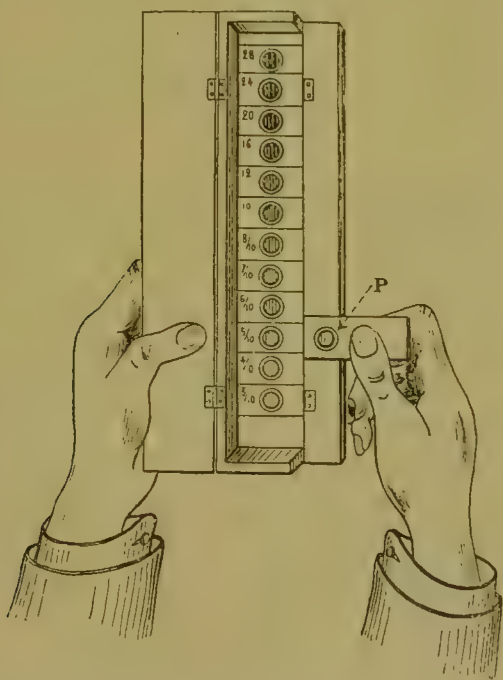


Fig. 22.—Holzknecht's Chromoradiometer.

At last he discovered a saline solution which undergoes a colour change proportional to the quantity of Roentgen rays absorbed by it. The composition of this saline solution has been hitherto kept secret.

This is the principle of Holzknecht's chromoradiometer. *Dr. Béclère*, on his return from Vienna, where he saw it employed in treatment, exhibited it to the Société de Dermatologie on November 6, 1902. He thus describes it:

'Holzknecht's chromoradiometer consists of two parts—a series of reagents and a graduated scale as a standard of comparison.

Each reagent consists of a quantity of the salt dissolved in some transparent substance, and contained in a small capsule. This is placed on the patient's skin close to the spot which is to be irradiated. The capsule is fixed on a card, which may be used for the notes of treatment, and a new capsule is required for each case.

'The graduated scale is formed by twelve of these capsules enclosed in a box, which preserves them from the light. These are all of a greenish-blue colour, which increases in intensity from one end of the series to the other. Each has a number, which indicates the quantity of rays absorbed by the capsule, according to a unit chosen by the inventor. This unit is indicated by the letter H.

'The scale extends from 3 H. to 24 H.

'The mode of employing the chromoradiometer is the following: A capsule is placed near the part to be treated. The exposure is interrupted from time to time, in order to compare the colour of the reagent with that of the scale. This is repeated until a tint is obtained which corresponds to the precise dose required. It is not necessary to complete this at one sitting. In the interval between two exposures however, the reagent should be kept in the dark. Moreover, if the first and last sitting are separated by a longer interval than five days, it is better to push the discoloration a little further, since in the interval the skin has had an opportunity of recovering from the impressions made by the Roentgen rays.

'The quantity of rays which are required for each case is extremely variable. It varies with age, with the region of the body, with the presence or absence of inflammation, with the pathological changes, and with the object of the experimenter—either to produce a stimulation, a slight irritation, a depilation, or a destruction of morbid products.

'The advantages of this method,' says *Béclère*, 'are evident. Its safety and facility place radiotherapy at the disposal of all dermatologists. It enables us to attain the exact dose with rapidity, without danger of exceeding it, and thus diminishes the duration of treatment, and prevents accidental dermatitis both in the patient and operator. Finally, it enables observers to compare their results by furnishing them with a means of measurement common to all. By its aid one can determine the exact degree of

reaction desirable for each pathological condition, the quantity of the rays suitable for each region of the skin, for different morbid processes, and moreover, the relative efficacy of different modes of exposure, either by large doses or by more frequent fractional doses.'

Holzknecht's method is equally available for measuring the complex radiations emitted by radio-active substances. It is well known how difficult it is to measure the radio-activity of different specimens of these substances. Supposing we desire to measure the amount of rays absorbed by the skin during an exposure to a radio-active substance. We expose a capsule of the reagent to the radio-active substance under the same conditions, and we continue the exposure until a degree of coloration is obtained equal to one of *Holzknecht's* units H.

From this we may calculate how many such units would be absorbed in an hour. This number might be taken as indicating the therapeutic activity of the radio-active substance. A certain sample of radium, for example, may be said to give off a certain number of *Holzknecht* units per hour, just as an accumulator is said to furnish a certain number of ampères per hour.

A fresh pastille is not required for each exposure. The same one may be used again and again, until it has attained the maximum degree of coloration on the scale. It may then be regenerated by exposure to light, although it never quite regains its original tint.

Holzknecht's apparatus is difficult to procure and somewhat costly, as only twelve pastilles are supplied with the scale. We have therefore adopted a simpler method, similar to that adopted when *Benoist's* radiochromometer is used.

We determine once for all the quantity of H. units absorbed by the skin in a given time with given intensity of radiation, and by reproducing the same conditions we can always insure the repetition of the same dose of rays.

For example, for a certain distance of tube we determine once for all, the number of units (H.) absorbed in fifteen, twenty, twenty-five, or thirty minutes. Under similar conditions, and with the tube at the same distance, we can insure a similar absorption whenever required.

These determinations might also be made for different distances of the anticathode. The values thus obtained should then be tabulated, so as to give the time of exposure required for a

definite dose of the rays. This table would, of course, be applicable only to the particular installation for which it was constructed.

It will be prudent to verify the data thus obtained from time to time, so as to guard against errors due to an alteration of the vacuum in the focus-tube or to a possible variation in the output of the electrical apparatus.

Holzknecht and others have indicated the doses of X-rays suitable in different cases. We will leave the discussion of this question to a later portion of this work.

This method of measurement, perfect in theory, is often found very difficult in practice, and is still far from fulfilling the hopes which it aroused at its first appearance.

As *M. Huguier* remarks in his thesis on exact measurement in radiotherapy, the real difficulty lies in the correct appreciation of the varying tints. The difference in tint between two consecutive capsules in the standard scale is very slight, and it is often found most difficult to make the comparison accurately. To attain a satisfactory result, a good illumination is required, and we have often found it advisable to compare the capsules by daylight, always using the same angle of incidence.

Moreover if, as *Oudin* advises, we use soft, and therefore very active tubes, the exposure will be very short. The operation must then be continually interrupted to ascertain the tint of the registering capsule, in order to compare it with the standard. Moreover, it is doubtful whether on exposure the tint is immediately produced which corresponds to the quantity of rays absorbed—*i.e.*, whether the colour reaction is an instantaneous one.

We have frequently observed that this colour change does not occur immediately. A pastille showing a colour corresponding to 5 H. was found on examination next day to have increased to 7 H., although it had been kept in the dark.

Again, two pastilles exposed at the same time to the same tube do not always show precisely the same tint. Sometimes a slight difference may be observed, though such an occurrence is very exceptional.

In his inaugural thesis *Huguier* records similar observations. In spite of these imperfections, it must be allowed that the chromoradiometer has been of great service to radiotherapy. Thanks to this invention, we have now a valuable method of control, and

a means of comparing radiotherapeutic exposures reported by different writers.

The various technical details published in such reports are of scientific value only in so far as they indicate the quantity of X-rays actually absorbed. *Holzknecht's* method is the only one which records this quantity with any degree of accuracy. We trust that this instrument will be speedily improved, and we may then obtain the convenient and accurate indicator we have sought so long. In any case, *Holzknecht* will always be gratefully remembered as the inventor of this most ingenious apparatus. The chromoradiometer will, we hope, in the near future do for radiotherapy what the photometer has done for photography.

Experiments in this direction have been made by other investigators. An attempt has been made to utilize the colour changes which occur in barium platinocyanide, but there is always the difficulty of obtaining a satisfactory scale of comparison. We require a substance which will retain its coloration after exposure, otherwise the scale of comparison must be produced in water-colours, which leads to many complications.

Quite recently *Freund* has described a new radiometer of his own invention, to which he ascribes some advantages over that of *Holzknecht*. His apparatus is based on the colour changes of a 2 per cent. solution of pure iodoform in chloroform. The solution normally retains its colour unchanged for a period of forty-eight hours. On exposure to the action of the X-rays it changes colour, owing to the liberation of iodine. Its sensitiveness is so great that a difference of tint may be observed between two portions of the solution, one of which has been exposed to the rays for a period of three minutes, whilst the other is screened from their action. *Freund's* solution shows a change of tint in six minutes equal to that attained in ten minutes by *Holzknecht's* pastilles. The glass of the containing vessel does not interfere with the production of these phenomena.

We have had no personal experience of this apparatus, but it appears to be more delicate than that of *Holzknecht*.

We have to thank *M. Sabouraud* for the communication of a new method of measurement which he has devised in collaboration with *Dr. Noiré*.

The following is a verbal transcript of his description of *Sabouraud* and *Noiré's* X-ray-radiometer :

'Up to the present *Holzknecht's* is the only method at our disposal for measuring the amount of X-rays absorbed by the skin during an irradiation. It has many advantages. The pastilles are simple and convenient, and give us a measurement unattainable in any other way. The method has, however, some drawbacks. The pastilles are a speciality, obtainable only from the maker. This inconvenience has been especially felt in France, where the pastilles have been unobtainable for the last six months. This speciality, of secret composition, is moreover of very high price, the pastilles costing two shillings each. A pastille may, it is true, be used more than once, but each time it loses something of its sensitiveness and accuracy.

'Another and a more important objection to *Holzknecht's* pastilles is the fact that their colour continues to grow darker for some time after the cessation of an exposure. At the end of an operation, therefore, the tint does not accurately measure the amount of radiation absorbed.

'Allowance must be made for the occurrence of this darkening subsequent to exposure. In the method devised by *Sabouraud* and *Noiré* all these inconveniences are obviated. Barium platinocyanide is the reagent used. Paper is impregnated with this substance by employing an emulsion of collodion and amyl acetate. It is therefore of the same composition as the screens employed in radioscopy. This paper grows darker on exposure to the X-rays, the depth of colour increasing with the length of exposure. The tint is compared with a scale in water-colours of three degrees of intensity;

'1. The colour of the barium platinocyanide unchanged by the rays.

'2. The tint corresponding to 4 H. in *Holzknecht's* units, which is the smallest quantity of X-rays giving an appreciable therapeutic reaction.

'3. The tint corresponding to 5½ H. on *Holzknecht's* scale. This amount of radiation cannot be exceeded without producing the initiatory signs of radiodermic erythema on the skin.

'The following are the advantages which this barium platinocyanide paper possesses over *Holzknecht's* pastilles :

'1. The process is not a secret one. Everyone may use it, and everyone is free to make improvements and modifications.

'2. Its cost is but small. A fluorescent screen, costing a guinea,

can be cut into several thousand fragments, each of which is sufficient for an exposure.

'3. The same fragment may even be used over and over again, provided it is always exposed to the action of daylight after use until it has regained its original colour.

'4. On the cessation of the exposure, the progress of the darkening ceases at once.

'5. *Sabouraud* and *Noiré's* prepared paper is more easily compared with their scale than are *Holzknecht's* pastilles with the corresponding standard.

'There are however, two drawbacks to this method which are clearly recognised by the inventors. On exposure to light, the paper loses colour rapidly, so that it must be immediately compared with the coloured scale, since a delay of a few minutes will alter its tint entirely. This disadvantage, however, only needs to be recognised in order to be avoided.

'A more important drawback is that the platinocyanide paper is much less sensitive than *Holzknecht's* pastilles. Whereas the latter may be placed at the same distance as the patient from the tube, *Sabouraud* and *Noiré's* screen must be placed much nearer, in order to get any effect. If the anticathode is at a distance of 6 inches from the patient, the screen must be placed 3 inches from the centre of the tube. This is a most important point, and must not be neglected.

'This determination of the quantity of rays by means of barium platinocyanide is very easily effected, and insures to both patient and operator a degree of safety hitherto unattainable.

'The fact that barium platinocyanide changes colour under the influence of the rays has been long known. *Sabouraud* and *Noiré*, by devising a simple scale of comparison for the changes in tint, have rendered it of practical utility. They have kindly provided us with a specimen, and we hope soon to be able to test it practically. It is simple, and will therefore prove of great value to the radiotherapy of the future.

'The fact that the indicator used rapidly loses its colour on exposure to daylight may perhaps be regarded as an objection to this method. The coloured scale is difficult to prepare, for, owing to the brilliancy of the platinocyanide, it is not easy to reproduce its tint in water-colours. These are, however, mere difficulties of construction, which in no wise diminish the value of the method.'

Quite recently *Sabouraud* and *Noiré* have simplified the apparatus by suppressing the intermediate tint, and only supplying two coloured pastilles, one giving the normal colour and the other the tint corresponding to *Holzknecht's* 5 H., the limit which cannot be exceeded without producing radiodermic erythema (*Sabouraud*).

The apparatus is thus reduced to its simplest form.

If we desire to obtain a greater degree of absorption than 5 H., we may proportionally increase the time of exposure.

This apparatus is however, still far inferior in value to *Holzknecht's* chromoradiometer, which has also been recently modified. The old colour scales may be used with the new Holzknecht pastilles. We also understand that the price will be lowered, and, what is still more important, that there will be greater facilities for obtaining the pastilles.

5. *Gaiffe's Milliampèremeter.*

An apparatus was exhibited by Messrs. Gaiffe at the meeting of the Société de Physique which enables us to measure the strength of the current passing through a focus-tube. It is a very valuable addition to our instruments of precision. With their new transformer it is particularly useful, since with a closed magnetic circuit any variation of current is due to the changes of resistance in the tube itself. As there is no interruptor, the transformer is governed by known and unvarying laws, and the electric current in the secondary circuit will remain unchanged so long as that in the primary is kept constant.

The following is the account of this invention, given to the Société de Dermatologie by *M. Brocq*, in collaboration with the author:

'Messrs. Gaiffe have succeeded in devising a practical means of measuring the current passing through a focus-tube. They have constructed a very sensitive milliampèremeter, which can be introduced into the secondary circuit supplying the tube. It may be read without interrupting the action of the tube, thus enabling us to detect any variation in the resistance of the tube, and to maintain it at a definite value for as long a period as may be required.

'If the voltage in the primary be kept constant by means of a regulating rheostat, any variation of current indicated by the

milliampèremeter can only be due to variation of resistance in the focus-tube.

'Such variation is caused by a change in the vacuum of the tube. If the current decreases, it is because the tube has hardened: if the current increases, the tube has become softer. A change in the penetration of the rays accompanies this change in resistance.

'If we keep the voltage in the primary constant, we can, by means of the osmo-regulator, adjust the focus-tube so as to give rays of any required degree of penetration, the degree being measured by means of Benoist's radiochromometer.

'When this is done, the voltage in the primary and the current registered by the milliampèremeter should be noted. The latter is easily read, as the needle does not oscillate. If any variation occurs in the vacuum of the tube, the needle of the milliampèremeter will be deflected. The vacuum must then be regulated by means of the osmo-regulator, until the needle resumes its original position. By this means we are able to maintain the rays at the same degree of penetration.

'Supposing, for instance, we are using a Chabaud focus-tube. With a pressure of 45 volts in the primary circuit, and a current of 2 milliampères through the tube, we get rays of a degree of penetration corresponding to No. 6 on the Benoist scale. The tube may be removed and used with a different transformer; its vacuum may be altered, rendering it harder or softer. On connecting it to the original transformer, with a pressure of 45 volts, we need only adjust the vacuum until a current of 2 milliampères passes, and we may be certain that the X-rays emitted are of No. 6 degree of penetration.'

We have now the necessary data for comparing different tubes, since for a given tube, a given current and voltage always produce the same quality of rays; and with a given voltage, the penetration of the rays varies inversely as the current through the tube. It should be possible by the universal adoption of a common standard (Benoist's radiochromometer, for example) to draw up tables which will give the degree of penetration of any focus-tube in terms of the electrical constants of the transformer employed.

This scheme might easily be realized, and Messrs. Gaiffe have already constructed such tables for use with one particular type of focus-tube.

Hitherto the spintermeter has been our only means of detecting variations in the resistance of the tube. The laws which govern its action are however but little known, and it only indicates variations of considerable magnitude, and moreover, only such as increase the resistance of the tube. It is in fact, merely a maximum indicator. The milliampèremeter, on the other hand, registers variations of resistance in either direction, and is thus a very valuable addition to our armamentarium.

Further, Gaiffe's experiments seem to prove that with the same voltage in the primary and the same current in the secondary, different tubes will give approximately similar results. This obtains even with tubes of different models by different makers, provided only that the anticathodes are of similar material and form, and that the glass employed is equally transparent. Gaiffe's apparatus also enables us to estimate the quantity of X-rays emitted by the tube. As long as the electrical constants and the voltage and ampèrage remain unaltered, the quantity of rays emitted will be the same. If the voltage and ampèrage are increased, the quantity of rays will be greater and the quality or penetration power will be altered at the same time.

By means of the osmo-regulator we may adjust the focus-tube to give out rays of the original degree of penetration. Notwithstanding this alteration, the quantity of current through the tube will still be greater than it was at first, and this will be indicated by the milliampèremeter.

To make this clearer, we will suppose that we have a current of 2 milliampères in the secondary, with a pressure of 45 volts in the primary, while the rays are of No. 6 hardness. If the pressure in the primary is increased to 60 volts, the milliampèremeter will indicate 3 milliampères, instead of 2, and the rays will be of No. 7 hardness.

On heating the osmo-regulator, we may decrease the vacuum, until the rays, as measured by the radiochromometer, regain their No. 6 hardness. The needle will now indicate 2·5 milliampères; the quantity of rays has therefore been increased in the ratio of 2 to 2·5.

Although this instrument does not give an absolute measurement of the quantity of X-rays, it is a useful means of comparing the amount of rays of a given degree of penetration emitted at different times.

If we may trust Gaiffe's experiments, we must admit his formula: 'For a given degree of penetration, the quantity of X-rays emitted is proportional to the intensity of the current in the tube.'

We desire to emphasize the chief advantages resulting from the use of the milliampèremeter:

1. The facility with which the tube can be regulated, so as to give any required quantity of X-rays up to the maximum obtainable, without injury to the tube.

2. The possibility of keeping the quantity of rays constant during an exposure.

3. The ease with which data may be recorded which enable us to replace a tube in precisely similar conditions after any interval of time.

4. The introduction of a system of measurement by means of which different operators can reproduce an irradiation under identical conditions.

Far from supplanting earlier instruments of measurement, the milliampèremeter is a valuable addition to their number and greatly facilitates their use.

It can be used equally well with a Ruhmkorff coil or a static machine. With neither of these instruments however, are we able to insure the constancy of the electrical conditions, consequently the indications of the milliampèremeter will not be as precise as it is when Gaiffe's generator is used.

With a static machine, for instance, the milliampèremeter may show a continual change in the quantity of rays emitted, even when the vacuum is kept constant, and the penetration of the rays, as measured by the radiochromometer, is unaltered.

In spite of these drawbacks, no radiotherapeutic installation is complete without this most valuable instrument.

6. *Stand and Focus-Tube Holder for Radiotherapy. Localizer.*

In the practice of radiotherapy in France we have, until quite recently, been content to fix the tube on any available support, to place it as near as possible to the surface to be irradiated, and to protect neighbouring parts by means of a sheet of lead.

The disadvantages of this primitive method of procedure are numerous.

1. It is not always easy to fix the tube in the most advantageous position.

2. There is a risk of upsetting or breaking the tube.

3. There is danger of an electric shock if the tube or the leads are brought too near to the patient.

4. The protecting lead mask is heavy, fatiguing, and in many cases difficult to adjust.

5. It is difficult to prevent movements of the patient, which may interfere with the application.

6. It is not easy to centre the tube satisfactorily. To obtain the best possible results, the rays which are normal to the anticathode should fall perpendicularly on the centre of the area to be treated.

7. In each case the distance between the anticathode and the skin should be determined by considerations of the area of the surface to be treated. It is very difficult to determine this distance accurately.

8. The operator suffers from being constantly exposed to the X-rays, unless he is protected by leaden gloves and masks.

We have devised an apparatus which obviates, at all events, some of these disadvantages. It is the result of experiments made at the Broca Hospital, in *Dr. Brocq's* electrotherapeutic department.

A Chabaud tube, of either the large or small model, is enclosed in an ebonite box somewhat like the tube in shape. This box is composed of two similar caps. The line of junction between these is in the plane of the anticathode (O), and they are fastened together by screws (U), in such a manner that they can be easily separated. The general appearance is that of a sphere, with cylindrical appendages on either side, which enclose the two electrodes of the tube. On the diameter at right angles to the cylinders are two apertures. Through one of these passes the osmo-regulator (N), the other (BB′) allows the passage of the Roentgen rays. The tube is accurately centred by means of a double adjustment (*b.c.*), so that the focus of emission situated on the anticathode may be exactly opposite the centre of the aperture for the X-rays. This is attained by means of two slides at right angles to one another, as shown in the accompanying illustration (Fig. 23).

The aperture for the X-rays is furnished with a metal socket,

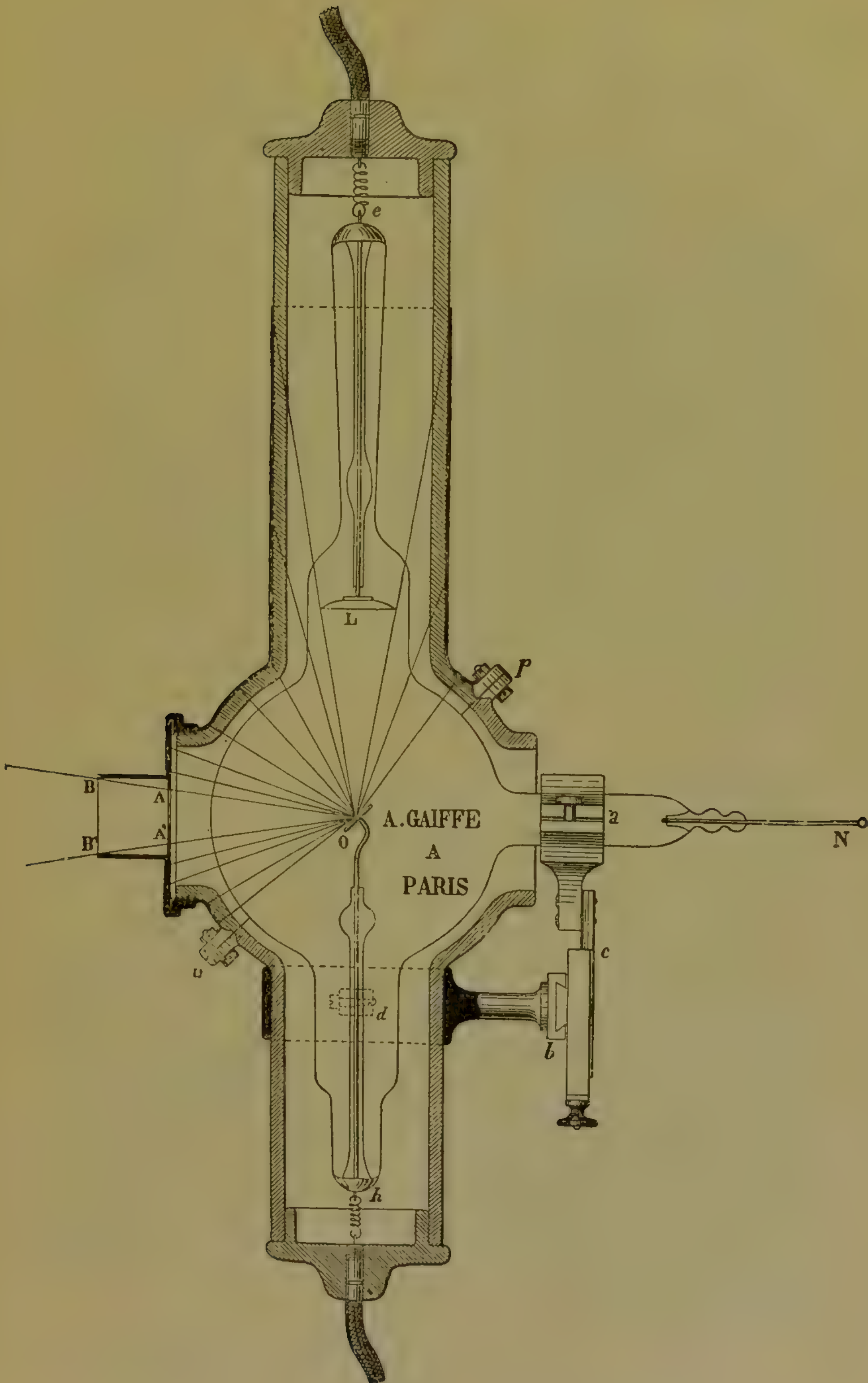


FIG. 23.—BELOT'S LOCALIZER. (Scale, one-third.)

into which tubes of various lengths and diameters may be screwed. By their means the radiation can be concentrated on any portion of the body—even the os uteri or the tongue.

The length and section of the tubes are so proportioned as to give the greatest possible degree of radiation compatible with uniformity of illumination over the irradiated area. The relation of length to diameter is determined by two laws, which are equally applicable to rays of light and to X-rays. These are the law of the inverse square and the law of sines.

Mathematical considerations show that a definite length of the localizing-tube is required for each diameter. The X-rays are emitted as a conical beam, and it is therefore evident that in order to obtain the uniform illumination of an area 8 centimetres in diameter, the anticathode must be placed further from the skin than when the surface to be treated is only 1 centimetre in diameter. At the end nearest the anticathode the localizing-tube is furnished with a metallic diaphragm (AA′), the aperture of which is of such a size as to prevent the passage of any secondary radiations.

Every particle of matter on which the X-rays fall emits other rays, which are termed by *Sagnac* secondary rays. These secondary rays pass in all directions, and may in their turn produce tertiary rays.

The properties of the secondary rays are not in all points identical with those of the X-rays which excited them, and therefore their production should be obviated as much as possible.

A sheet of lead covers the outside of that portion of the box which is exposed to the action of the X-rays. A small opening is left, in which a *Holzknecht* pastille may be placed. The localizer is attached by means of an aluminium support to an adjustable stand.

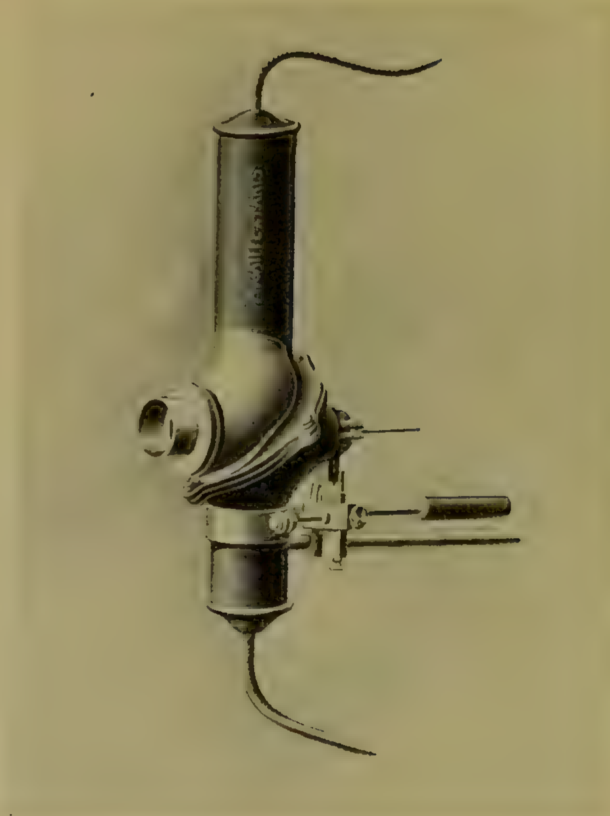
All the metallic parts are in electrical connection, and 'earthed' by means of the pedestal. The localizer can therefore be handled without danger, and the patient may even press the affected spot against the aperture of the tube, as is done in the application of phototherapy. The following are some of its advantages:

1. The apparatus can be used in any direction, the patient being horizontal or in a sitting position.

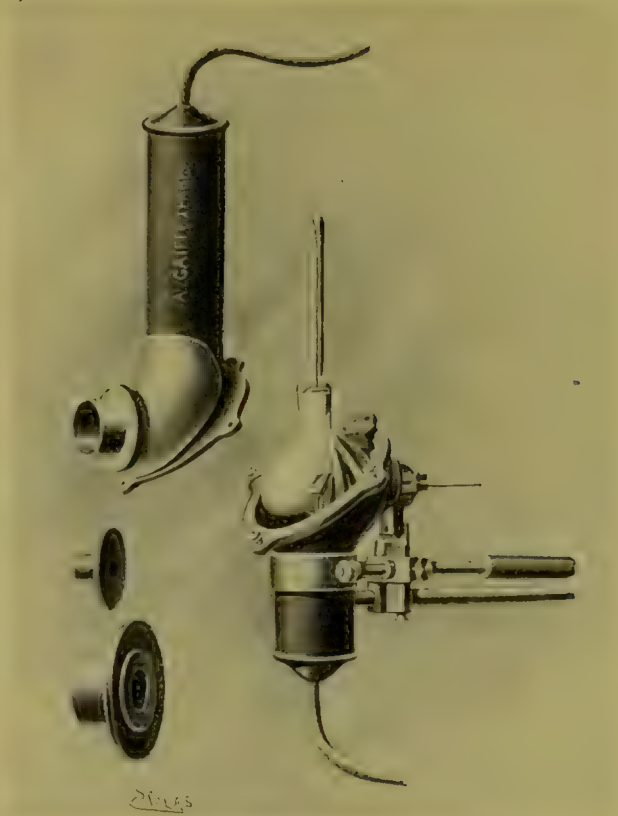
2. Complete protection against accident.

3. Complete suppression of electric discharge due to the magnetic field in the vicinity of the focus-tube.

PLATE III.



Shut—ready for use.



Open—showing the focus-tube.

BELOT'S LOCALIZER FOR RADIOTHERAPEUTIC TREATMENT.

To face p. 66.

4. A lead mask is no longer required; a tube, of appropriate diameter, sufficiently isolates the affected part.

5. As the patient may rest against the localizing-tube, displacement is less likely to occur, and is more easily remedied.

6. The anticathode is mechanically adjusted, in a properly

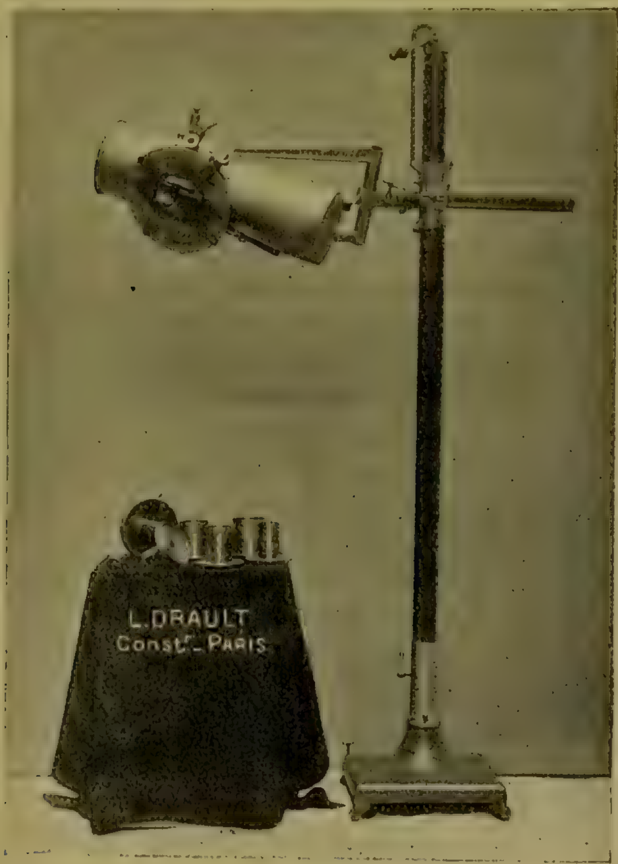


FIG. 24.—STAND FOR FOCUS-TUBE.

centralized position, at the right distance for equal irradiation of the affected area.

7. The shape of the tube itself determines the distance between the anticathode and the skin. A tube is chosen whose aperture will embrace the whole of the surface to be treated. This has been constructed of such a length as will ensure perfect illumination. Each tube is marked with a number, which indicates the distance between the anticathode and the skin.

8. The tube insures the total suppression of all X-rays which are not absorbed by the skin, thus shielding both the patient and the operator from the danger of accidental dermatitis.

If we desire to expose a larger surface, as in cases of pruritus, the shielding-tube is omitted, and the surface is exposed directly to the focus-tube, taking care to place this at a considerable distance from the skin, and to alter the position of the tube continually in a plane parallel to the skin. By this means we may obtain an extended and equable exposure. An aperture for the radiochromometer has been purposely omitted, since the observation of such a small surface would be impossible while the focus-tube is in action. In its stead we may determine the quality of the rays once for all; then, by adjustment so as to obtain the same electric constants and the same spark-gap, we are able at any time to reproduce rays of the same degree of penetration. Moreover, Gaiffe's milliampèremeter enables us to estimate with much greater accuracy the vacuum of the tube, its resistance, and the quality of the rays which are emitted.

With a milliampèremeter in the secondary circuit, observations with the radiochromometer become superfluous.

This localizing instrument is very light and easily manipulated, and therefore far preferable to the old-fashioned radioscopic supports.

Sabouraud uses a modification, manufactured by Messrs. Drault, which is of larger size, and fits any variety of focus-tube. It can be used both for radioscopy and radiotherapy, but is better adapted for hospital use.

Michaud and *Krouchkol* use a similar apparatus, made by Messrs. Dean of London, consisting of a hemisphere of crown-glass, supplied with application-tubes, also of crown-glass, which are made to fit the various apertures of the body. This invention not only localizes the rays and protects the operator, but enables one to watch the action of the tube through the transparent glass. It is however heavy, and interferes with the free movement and adjustment of the focus-tube. This induced us to construct our localizer of ebonite and lead, rather than of crown-glass, as we had at first intended.

A universal support, enabling the tube to be placed in any position, has been designed by *Dr. Rivière* of Paris, and constructed by J. Lacoste. The field of action is limited by a screen of lead

glass, and the focus-tube is fixed to this by two bands of leather. The disadvantage of this arrangement is the difficulty of centering the tube accurately.

7. *The Value of the Electric Constants in Comparing the Observations of Different Authorities.*

In order to give the greatest possible precision to reports of radiotherapeutic treatment, most authors are careful to note the electric constants of their induction-coil. Hence a belief has arisen that for the treatment of a given case, a certain voltage and ampèrage is necessary. For instance, one hears it said, 'When the coil is used for therapeutic purposes, the current in the primary should be reduced to 4 ampères and 15 volts.' In 1902 *Gaston* and *Veira* thus concluded their report on X-rays to the Société de Dermatologie: 'The whole matter is dominated by the question of the ampèrage and voltage in the primary current.'

In reality these measurements are of but little value—the question of importance in comparing two coils is the current and pressure in the secondary circuit. With a Wehnelt electrolytic interruptor the anticathode may not get red-hot with a current of 20 ampères at 220 volts, whereas, after a slight alteration in the adjustment of the interruptor, it may become white-hot with a current of only 8 ampères.

When we observe such differences of output under different circumstances when using the same coil and the same interruptor, we can easily imagine what enormous variations may occur when different kinds of interruptor are employed, when the rapidity ot break is changed, when the windings of the primary and secondary are varied, or an alteration made in the break condensers. The slightest variation alters the output of a coil, even in the length of the leads from the condenser to the interruptor, or in the insulation of the coils of the primary. All these considerations make it impossible to calculate the output of a coil, or to compare it with any other coil of different make or size. The data published by experimenters are only of use with the same coil and the same interruptor, and with the adjustment of that interruptor unaltered.

This state of things is irremediable so long as interruptors are employed.

Messrs. Gaiffe have given us the results of experiments illustrating this variability.

At the same time, with the same coil and the same tube, identical results were obtained from the following:

1 ampère at 220 volts, using the Contremulins-Gaiffe break.
7 ampères at 16 volts, using the Carpentier break.
7 ampères at 110 volts, using a Wehnelt break.

We must not, however, conclude that the construction of induction-coils is wholly empirical. Although the output of a coil cannot be expressed by a mathematical formula, yet experience will enable us to foresee probable variations.

For instance, a diminution in the number of coils in either the primary or the secondary circuit will diminish the coefficient of induction. If the other conditions remain unaltered, this will entail a greater expenditure of current in the primary circuit.

The value of the mean current only is indicated by the ampèremeter. For a given maximum current this reading is higher with a small voltage, owing to the increased rapidity of induction.

Whatever the interruptor, the only important point is the power, measured in watts, available at the terminals of the coil. This will be the same, and therefore the efficiency will be the same, whether we employ in the primary circuit a current of 4 ampères at a pressure of 15 volts or a current of 1 ampère at 60 volts. The induction-coil used should be adapted to suit the conditions under which it is employed.

The maker should mark on every coil the precise pressure and current which give the greatest efficiency, and these conditions should be carefully adhered to.

The same current may be obtained in the secondary by very different conditions in the primary. These may vary according to the pressure and current available, and the nature of the electrical source, whether continuous or alternating, etc. In similar conditions, the best coil is that which produces the greatest result with the smallest expenditure of current.

The efficiency of an induction-coil—*i.e.*, the wattage between the terminals of the secondary—should be capable of verification.

Hitherto we have been unable to measure this in a practical manner.

It is true that with Gaiffe's milliampèremeter we can measure the intensity of a high-tension current; but the difference of potential between the terminals of the secondary cannot be measured either by the Bichat and Blondlot's electrometer, or Henlé's gold-leaf electroscope, or even by Broca's novel instrument, which consists of a silvered filament of quartz in an electric field.

Hence we are constrained to measure the difference of potential between the terminals of the primary circuit. With a transformer with closed magnetic circuit, we can estimate the voltage in the secondary from that of the primary. For a given transformer we ascertain once for all what voltage in the primary will give a certain electric pressure in the secondary. This ratio will not vary, so long as the apparatus is intact and in good order, since in this form of generator there is no interruptor to vitiate the results.

So far as regards the quantity of X-rays produced, the voltage employed is not of the first importance. Much more so are the differences inherent in the Crookes tubes themselves. With the same installation, the results may be completely altered by changing one focus-tube for another, even of the same pattern.

It is still more impossible to compare the output of an induction-coil with that of a static machine, although both are sources of high-tension electricity and either may be used to produce X-rays.

Even two static machines are not comparable. Their efficiency depends on their form, on the rapidity of rotation, the state of insulation, the wear of the ebonite discs, the temperature, the hygrometric state of the room, and many other conditions.

In an induction-coil the frequency of the interruptions in the primary circuit is a factor of prime importance. Some observers prescribe a frequency of twenty per second. Others, with whom however we do not agree, assert that the efficiency of a focus-tube depends entirely on the frequency of emission of the X-rays, and therefore on the frequency of the break.

The result of increasing the number of interruptions per second is exceedingly complicated. The number of sparks is increased; but since the duration of the passage of each spark is decreased, the maximum current is diminished. We thus get a fall in the

maximum voltage of the secondary, with an increase in the number of sparks, and the illumination of the tube becomes more equable. Practically the result is the same, since the increase in the frequency of emission is compensated for by a diminution of the length of each period of emission. This only holds true within certain limits, which vary with the make of coil and interruptor.

Of greater importance is the duration of the passage of the current between the interruptions. In the Contremoulins-Gaiffe break the rapidity of rotation of the disc determines the frequency of the interruptions. By altering the adjustment of the collecting brushes, it is possible to increase the time during which the current passes between each interruption, without varying the speed of rotation. By this means, without altering the spark-frequency, we are able to increase the maximum current in the primary, and thus obtain a higher efficiency. If the maximum intensity is too great, the excess of current will merely be wasted in heating the primary coil.

In publishing their results, some recent observers note the number of plates in the condenser. This is only of theoretic interest. Increasing the capacity of the condenser attached to the break terminals (Fizeau's condensers) above a certain point, only results in lowering the electro-motive force of self-induction in the primary. This will diminish the length of the spark-discharge. On the other hand, if the capacity is too small, the break will occur more slowly, and there will be a similar diminution of the spark.

Practically the enumeration of the number of plates in the condenser is useless. A knowledge of the capacity is important, but this depends not only on the number of the plates, but on their surface area, the thickness of the dielectric, and the shape of the condenser. Two condensers, precisely similar in appearance, may have a difference of capacity of 0·5, or even 1 microfarad.

Oudin and others attribute great importance to the degree to which the anticathode is heated. A cherry-red heat is the temperature to be aimed at. It is true that the cathode is heated to a greater or less degree according to the number of cathode rays impinging on its surface. It is however very difficult to observe the colour accurately. It will differ with the nature of the anticathode, the size of the tube, its artificial cooling, etc. Moreover, in some tubes the anticathode does not become red-hot at all.

Information regarding the value of the electric constants is not, however, altogether useless. It is always of interest to know the details of an experiment. What we wish to emphasize is that too great importance should not be given to a set of figures which have no value except for the particular installation under consideration. The important factors should be independent of the observer and his particular installation. These are, as we shall see further on, the quality and the quantity of the rays absorbed.

CHAPTER IV

THE THEORY OF THE ROENTGEN RAYS

EVER since *Roentgen's* discovery such a host of observations have been made, and so many theories have been broached, that many are bewildered by a confusion which, after all, is more apparent than real.

One hears of X-rays proper, of *Sagnac's* secondary rays, and of the spontaneous radiations of radio-active matter discovered by *Becquerel* and *Curie*, which are in their turn subdivided into classes according as they are more or less deviable in a magnetic field. We hear also of cathode rays, of *Goldstein's* canal rays, of *Lenard* rays, which pass through an aluminium window in a Crookes tube, and of rays produced by the impact of ultra-violet light on a zinc plate. The number of the different radiations is legion.

In reality we recognise two new types of radiation, and two only —one, that of the X-rays; and the other, that of the cathode rays. There seems to be a fundamental distinction between these two classes, and all the new radiations discovered of late years may be placed in one or the other.

We shall not discuss the cathode rays here; we shall have to return to them later on in their character of generators of the Roentgen rays.

In discussing the general properties of X-rays we shall quote from *Bouchard's* 'Treatise on Medical Radiology.'

Origin of X-Rays.

It is important to determine the exact point of origin of the X-rays.

J. Perrin and others proved that X-rays are produced wherever the cathode rays impinge on a solid body; hence the cathode rays may be said to be the direct progenitors of the Roentgen rays.

Tommassin thus explains the formation of cathode rays in an exhausted tube:

'The electric flux, starting from the anode, flows through the rarefied air of the tube, along the lines of force, and forms its own conducting-path of polarized radiant matter.'

A similar phenomenon may be observed in the so-called 'electric phantom,' where one may see the projection of tiny jets of the conducting powder in a non-conducting liquid.

In the focus-tube the electric flux is of an oscillatory character. Hence there is a periodic rupture of the contacts between the particles of the conducting medium, and the resulting vibrations become visible as a luminescent glow. The lines of force in the electric field embrace the cathodic mirror on every side, but the densest portion impinges on its concave surface and rapidly heats it. The consequent rise of temperature increases the rarefaction of the gas in the proximity of the cathode, and gives rise to Hittorf's 'dark space,' which is due to interference. Thus the increase of the dark space with a stronger current may be readily explained.

The quantity of X-rays emitted by a tube increases with the number of cathode rays impinging on an obstacle placed in their path. The nature of this obstacle is also of importance. Heavy metals produce X-rays better than glass. Among metals, platinum is the best, not only because it emits a greater number of X-rays, but because it is better able to resist the high temperature.

In the usual form of focus-tube the X-rays take their origin from the focus-plate, a plate of platinum placed at the point where the convergent rays emanating from the concave cathode meet. Only a small number of diffused cathode rays impinge on the walls of the tube, and under their action the glass fluoresces with a green colour. The wall of the tube will not allow the cathode rays to pass, but permits the exit of the X-rays, with only a certain diminution in their intensity. The diffused cathode rays give rise to X-rays where they strike the walls of the tube; their quantity is however not sufficient to heat the tube to any great extent. The focus-plate of the anticathode may be raised to a red heat with impunity. If the anticathode is correctly placed at the focus of the cathode, only a small point of the anticathode will emit X-rays. The radiation of X-rays from the anticathode takes place in all directions, the rays forming the radii of a hemisphere, bounded by the plane of the anticathode. The corresponding

hemisphere of the focus-tube is illuminated by the cathode rays which always accompany the X-rays.

The emission of X-rays follows a law totally different from that which governs the diffusion of light from an unpolished surface. *Gouy* at first and *Roentgen* afterwards showed that the intensity of the X-ray radiation is the same in every direction, diminishing only at a very oblique angle. For instance, the X-rays issuing at an angle of 6° with the plane of the anticathode are of half the intensity of those coming off at right angles to its surface.

In radiotherapy it is best to make use of those X-rays which are emitted at right angles to the stream of cathode rays—*i.e.*, those rays which are in the position which would be occupied by the reflected beam, if the incident cathode rays were ordinary light rays.

Properties of X-Rays.

The first discovery of X-rays was due to one of their most characteristic properties. As will be remembered, *Roentgen* discovered them almost by accident. A Crookes tube, worked by a coil, was enclosed in a wooden box. A screen covered by crystals of platinocyanide of barium happened to be in the neighbourhood, and *Roentgen* observed that it became luminous, just as if it were receiving invisible ultra-violet rays. In like manner, a photographic plate received an impression from the new radiations.

When an opaque object was interposed between the tube and the fluorescent screen, a shadow of the object appeared on the screen—a shadow the intensity of which varied according to the nature of the substance of which the opaque body was composed.

The Crookes tube, the interposed object, and the shadow on the screen, are all in one straight line; it is therefore permissible to assume that the rays in question issue from the Crookes tube.

If now we place a second object in the path of the rays which form the shadow, the silhouette first formed still remains visible, provided that the second object is not too opaque. The silhouette, moreover, remains unaltered in position and shape. This observation proves, at least approximately, that X-rays are not refracted. In consequence of this property of rectilinear propagation through substances of varying degrees of density, the X-rays project a silhouette of an opaque body just as if it were completely isolated in space. The X-rays are not sensibly reflected at the surfaces of

bodies on which they impinge; and if they are diffused, it must be in an almost imperceptible degree.

The Roentgen rays have another most important property: they discharge an electrified body in their vicinity, and this whether the charge be positive or negative.

Metals are not opaque to the Roentgen rays, as they are to rays of light. The more heavy metals are the least transparent to X-rays. Even these, however, when in thin sheets, are traversed by the more penetrating rays, such as are produced by a Crookes tube of very high vacuum.

Glass, which is so transparent to light, is less so to the X-rays, which are absorbed by a sufficient thickness of it.

The phenomena of absorption of these rays appears to be wholly independent of the crystalline structure of the matter through which they pass.

The elements with high atomic weight are more opaque to the rays. This is the case with the ordinary heavy metals; the lighter metals, with low atomic weight, are usually transparent.

It may be said that the transparency of a body to the X-rays varies inversely as its atomic weight.

The Roentgen radiations are usually invisible to the eye. With highly penetrating rays, however, one may get a faint diffused light, occupying a circular field of vision. The rays follow a straight line through the refractive media of the eye, without suffering any deviation, and hence cannot produce an image on the retina.

The path of the Roentgen rays is absolutely rectilinear. Whether they traverse or merely impinge on the surface of a body, they are more or less disseminated. The degree of this dissemination bears no relation to the laws of reflection and diffusion of light under similar circumstances.

The radiations are heterogeneous in character; those of a more penetrating quality are able to pass through a thin sheet of aluminium, but with some diminution of intensity.

Roentgen rays are not reflected or refracted, and consequently cannot be polarized.

According to *Haga* and *Wind* the wave-length is only a few thousandths of a micron, or 2,000 times smaller than a wave of green light.

A pencil of X-rays in passing through matter becomes gradually enfeebled, but retains its rectilineal direction. Each particle of

matter which is struck by an X-ray emits other rays, the 'secondary X-rays' of Sagnac, which are thus derived from the primary X-rays issuing from the anticathode. These secondary rays radiate in every direction, and may themselves give rise to tertiary X-rays. This dissemination is not a mere diffusion, but rather a process of partial transformation of the primary X-rays. The secondary and tertiary X-rays are less penetrating than the primary rays which produce them.

Another most important property of Roentgen rays is their physiological action on the skin and on living cells—an action which we shall investigate later on.

Hypotheses on the Nature of the X-rays.

During the last seven or eight years the question of the nature of Roentgen rays has been much discussed.

Some time ago *Blondlot* measured their rapidity of propagation. This discovery does not positively indicate the nature of the rays, but it enables us to eliminate some of the hypotheses put forward.

As the result of his experiments, this eminent physicist concludes that the velocity of propagation of the X-rays is equal to that of the Hertzian oscillations. This gives them a velocity equal to that of light, since a series of classical experiments, also due to *Blondlot*, had already established the fact that the velocity of light and that of Hertzian waves are identical. 'These results,' says *Lucien Poincaré*, 'are of considerable importance. It would seem that two phenomena which are propagated with equal velocities should be of similar nature, or at all events that the medium of propagation in both instances is identical. The similarity of the velocity of the X-rays and of light tends to prove that X-rays are phenomena occurring in the luminous ether, and gives no support to the theory that they are due to the emission of material particles.

Blondlot's experiments do not assist us much in understanding the mechanism of the phenomenon, of which there are several hypotheses. They are completely in accordance with the theory of *Wiechert* and *Sir George Stokes*, who believe the X-rays to be due to a succession of independent pulsations in the ether, these pulsations originating at the point where the cathode stream strikes the anticathode. They are pulsations, not continuous vibrations

like those which produce the ordinary rays of the spectrum, but sudden, isolated, brief pulses in the ether, which, like those of light, are transverse in direction. According to theoretical considerations, such rays should travel with the same velocity as light; they should not suffer refraction or reflection, but should under certain circumstances exhibit phenomena of diffraction. All of these characteristics are presented by Roentgen rays, which are neither reflected nor refracted, but exhibit curious diffraction phenomena. These have been shown by *Haga* and *Wind*, and more recently by the researches of *Sommerfeld*.

These analogies, however, do not absolutely prove the correctness of Stokes's hypothesis. *Duhem* attributes the cause of this mysterious radiation to longitudinal vibrations, which would, as he has shown, be propagated in a dielectric medium with a velocity equal to that of light. Another theory is that X-rays are due to ultra-violet radiations of very short wave-lengths—ultra-ultra-violet light, as it might be termed.

This latter hypothesis, which appears to us to be the more natural one, accords with *Goldstein's* conception of their nature. As the result of a long series of experiments on the phenomena of absorption, he comes to the conclusion that Roentgen rays have a great resemblance to ultra-violet radiations.

It is a point in favour of this last conception that the X-rays thus readily fall into their place as varieties of phenomena already familiar to us.

PART II

CHAPTER I

THE EVOLUTION OF RADIOTHERAPY

The earlier experimenters with Roentgen rays were surprised to find a certain amount of cutaneous irritation arising in the parts habitually exposed to the rays. The surface of the skin became slightly inflamed, the hairs fell out, and itching, sometimes of terrible intensity, obliged the operator to discontinue his work. In some cases more serious lesions made their appearance. Bullæ and phlyctenulæ followed the erythema, and these in turn gave place to deep ulceration and scarring. These accidents happened to patients exposed to the rays during radioscopic examination, as well as to the operators themselves. We must remember that in the year 1896 it was often necessary to make very long exposures in order to ensure satisfactory results, the technique of the procedure being then in its infancy.

About the same time the idea seems to have occurred to more than one experimenter to make use of this cutaneous reaction for therapeutic purposes. They hoped more especially to obtain favourable results in cases requiring epilation. The first experiments were therefore made in cases of hypertrichosis and tinea. Later, other cutaneous affections were treated on the principle of setting up a substitutive inflammation.

It was surmised moreover, that this new variety of energy while traversing the body, might act on the deeper tissues. It was tentatively employed in cases of pulmonary tuberculosis and other deep lesions which proved refractory to ordinary therapeutic agents.

The treatment of cutaneous diseases by irradiation with Roentgen rays commenced on the Continent, and has rapidly spread. Reports of cutaneous affections treated, ameliorated, or cured by

this method, soon appeared in the foreign medical press. The names of *Schiff*, *Freund*, *Kümmel*, *Kaposi*, *Unna*, *Kienböck*, and *Scholtz*, remind us that long after the discovery of *Roentgen*, radiotherapy was practised almost exclusively by members of the German and Viennese schools. In 1901 *Oudin* asserted, 'To study the radiotherapeutic treatment of skin diseases we must go abroad. France has contributed but little to the progress of this method of treatment.' At the present day this can no longer be said. In France a large number of cases have been already reported, and it is to France that we owe the invention of many of those instruments of precision which are the foundation of radiotherapy as an exact science.

Many causes contributed to the late development of radiotherapy in France. X-rays were discovered in Vienna, and their technical application was more easily learnt by those who could profit by the experience of *Roentgen* himself.

Moreover, progress was much easier for those who were familiar with physical phenomena and the problems of pure science. It is possible that the majority of French practitioners are less occupied with these studies than their colleagues elsewhere.

'The delay,' says *Oudin*, 'was due in a much greater measure to the legal aspects of the case. In this country the medical practitioner is treated too often like a workman, and the accidents arising in the course of treatment are regarded as if they were caused by the carelessness of a mechanic. The law pressed heavily on physicians who set up a dermatitis in the course of treatment at a time when these accidents could hardly be avoided, as their cause was still unknown. The fear of legal prosecution, together with the paucity of technical instruction in the use of the Roentgen rays, contributed to delay the adoption of radiotherapy, and it remained a mere curiosity in the laboratory.' In 1901 *Oudin* condemned the new science in these words: 'As long as we remain ignorant of the agents which cause dermatitis, and until we are able to produce it or avoid it at will, it will be imprudent to practise radiotherapy, since the reaction occurs long after the cessation of the treatment, and may then be irreparable.'

In the evolution of radiotherapy two periods may be distinguished, the empiric and the scientific.

The first extended from the date of *Roentgen's* discovery up to the year 1900 or 1901.

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In the course of radiographic exposures certain phenomena of reaction were observed, such as redness and loss of hair. In 1896 *Marcuse Daniel* and *Delorme* published cases of this kind in which alopecia occurred, followed by dermatitis. In some cases this was a chronic reaction affecting the hands of the operator, as reported by *Richer* and *Londe.* In other cases, as shown by *Thomson*, the dermatitis was an acute one, purposely set up by experimenters on themselves or on others. This was the beginning of radiotherapy. *Schiff* and *Freund* were the first to use the X-rays systematically as a therapeutic agent, and they published some astonishing results obtained by the new method. The earliest cases treated in their clinique at Vienna were those of hypertrichosis, tinea, and other parasitic affections of the hair in which epilation was desired.

Little by little they attacked other affections of the skin, with very variable results. Following them, a number of dermatologists—German, English, and American, together with a few French practitioners—began to practise radiotherapy, and published results which were often contradictory.

This was the period of empiricism.

The nature of the active agent was still unknown; *Schiff*, *Freund*, and *Oudin* believing it to consist in the discharge of electricity; whilst others attributed the results to the X-rays themselves. The varying vacuum in the focus-tube was ignored; the same tube was used till it broke down, and the operator was surprised to find that different results followed treatment at the beginning and at the end of its life. Now and again a focus-tube would produce a terrible dermatitis without any apparent cause. A focus-tube was used for a long time without giving rise to any reaction; it broke, and the new tube suddenly set up a serious dermatitis. There was great discussion as to the best size of the tubes, and the various means of preventing accidents. Many were invented, each one more useless than the last.

The technical data were most meagre, merely the type of induction-coil and the tension and intensity of the current in the primary circuit being given. The time of exposure varied in an incredible manner. Some authors spoke of minutes, while others got no appreciable action after sittings of an hour's duration. Some experimenters placed the focus-tube close to the skin; others removed it to a considerable distance. The X-rays were applied blindly, the

operators knowing neither the nature of the agent they employed nor in what manner it acted. Radiodermatitis was greatly feared when it was unlikely to occur, and occurred when all precautions had been taken to avoid it. Empiricism reigned supreme. There was no means of measurement: radiotherapy was not yet a science.

In 1899 *Levy-Dorn* and *Albers-Schoenberg* attempted to clear up some of the obscurities. In the *Fortschritte auf dem Gebiete der Roentgen-Strahlen* they took the initiative, and asked the collaboration of all those who had any experience in radiotherapy. It is, however, to *Kienböck* that the honour of making radiotherapy a science belongs. He showed that the therapeutic effect was due solely to the Roentgen rays themselves, and that the electric effleuves had only a secondary effect.

Kienböck made a study of the focus-tube and its mode of action. He first demonstrated that the rays varied in penetration according to the vacuum in the tube. He differentiated between the soft, the medium, and the hard tube. In August, 1900, as the result of numerous experiments, he came to the same conclusion as *Sträter*: 'Soft tubes are active, hard tubes are very slightly active.'

He established a rational method of radiotherapy, based on his own experience, and studied the modifications produced in the skin and internal organs by the action of the X-rays.

Oudin undertook a series of researches on the nature of the active agent in radiotherapy. Commencing with the hypothesis that the preponderating influence was that of the electrical effleuves, he ultimately abandoned it. As a result of conclusive experimental evidence, he declared that the X-rays were themselves the only active agents, or, at all events, the principal agent, in radiotherapy. He studied the mechanism of radiodermatitis, and prescribed a definite technique for radiotherapeutic treatment, which he has since somewhat modified.

In 1902 *Scholtz* published an important work on radiotherapy, in which most of the questions in dispute were discussed in a masterly manner.

During this time the construction of instruments was greatly improved. Regulating focus-tubes were made, and *Benoist's* radiochromometer was introduced as a means of estimating the penetration of the rays.

Dr. Béclère invented the spintermeter, which gives us a measure of the resistance of the focus-tube.

Induction-coils were improved, and their efficiency was increased. New apparatus enabled us to make use of the public sources of electrical supply, and thus the power of the X-rays generator was greatly increased. Static machines of better design were introduced, and soon became common. The installation of an X-ray apparatus became much simpler, and the irradiation obtained more uniform.

Lastly, *Dr. Guido Holzknecht* discovered his chromo-radiometer, and placed us in a position to measure the exact dose of X-rays absorbed by the skin.

During recent years radiotherapy has greatly developed. On all sides cases are reported; cures become more numerous and accidents less common. The mechanism of the action of the X-rays is being closely studied, as well as the histological modifications which they produce. They are now applied in a methodical manner in those cases where their use is theoretically indicated. Moreover, thanks to the invention of instruments of precision, different technical methods may be compared. The practitioner may now hope to get identical results by following the prescribed conditions. Radiotherapy has passed from the domain of empiricism to that of an exact science.

To-day it is the most fashionable mode of treatment. In Germany, in Vienna, in Switzerland, in England, and America it is employed by hosts of practitioners. Some reserve it for the treatment of cutaneous disease, while others employ it in maladies of the most diverse nature. Competent observers have even gone so far as to affirm its curative action in deep-seated cancerous affections. In our opinion its chief use is in dermatological practice. In skin diseases, where other remedial measures have entirely failed, it frequently gives the happiest results.

Even yet we know but little of its effects. The future, we are assured, holds in store for us many surprises, and perchance many a disappointment.

CHAPTER II

THE ACTIVE AGENT IN RADIOTHERAPY

There has been much discussion as to the nature of the active agent in radiotherapy. The problem would be easy of solution if the Crookes tube produced nothing but X-rays. In reality the region round a focus-tube is the stage of a multitude of electrical phenomena. To the early investigators it seemed impossible that an invisible agent like the X-rays should be the cause of acute dermatitis. The origin of these accidents was therefore sought for elsewhere, and the alterations in the tissues resulting from a prolonged exposure were attributed to the most diverse causes.

It may be useful at this stage to investigate the different hypotheses regarding the nature of the active agent, and the experiments which were supposed to support them.

The determination of this question has a most important bearing on treatment, the course of which depends on our appreciation of the nature of the active agent. If the therapeutic action is due to the X-rays themselves, one would naturally use a soft tube, which produces them in great abundance. If, on the other hand, other agencies preponderate, the apparatus should be so modified as to increase their production.

Leopold Freund, in his work on radiotherapy, published in 1903, thus enumerates all the possible agencies which might be supposed to produce dermatitis, and a consequent therapeutic effect. The following is a complete list of all the phenomena observed in the neighbourhood of a focus-tube in action:

- Heat.
- Ozone.
- Cathode rays.
- Ultra-violet light.
- Emission of material particles.
- Roentgen rays.
- Electric discharges or effleuves from the tube.
- Electric or electro-dynamic waves.
- Unknown radiations.

It is only necessary to place a thermometer in the field of a focus-tube to assure ourselves that the temperature does not differ greatly from that of the surrounding air. Patients are not sensible of any increase of heat, and any slight rise in temperature occurring is much too small to affect the skin. Moreover, neither in their appearance nor in their mode of evolution do the results of X-ray dermatitis resemble ordinary burns.

Another hypothesis is that of *Tesla*, as reported by *Dr. Gilchrist*, which attributes the destructive action not so much to the X-rays as to the ozone they generate. The ozone was supposed to act on the skin all the more energetically in consequence of its increased warmth and moisture.

As *Freund* pointed out, this does not explain the occurrence of dermatitis on the back of a patient whose chest only has been exposed to the rays. Neither does it accord with two of the most fundamental properties of the X-rays—their cumulative action and their period of latency. Moreover, the sub-epidermic tissue is attacked by the X-rays, whilst the epidermis remains apparently normal. There is no reason why ozone should attack the deeper layers, while leaving the more superficial tissue intact.

Oudin, *Barthélemy*, and *Darier*, in their work on the accidents following the use of X-rays, entirely reject the ozone theory.

'One of us,' they say, 'for many years had studied the therapeutic action of ozone, and was in daily contact with apparatus producing it in large quantities. He had never experienced any cutaneous irritation such as appeared on his skin a few weeks after he commenced the study of the X-rays.

'The second objection is that a Crookes tube does not produce ozone unless it is connected to a condenser which is either earthed or connected to one of the electrodes—conditions which do not obtain in ordinary X-ray exposures. Moreover, we have exposed ozone test-paper to the radiations from a focus-tube for hours without effect. The presence of a small amount of ozone is due to the effleuves from the leads attached to the coil.'

Equally untenable is the hypothesis advanced by *Gilchrist*, *Ames*, and *Foveau de Courmelles* in 1897—viz., that the dermatitis is due to the action of cathode rays. As *Lenard* has shown, these are totally arrested by a thin plate of glass, although they can traverse a thin sheet of aluminium. The wall of the focus-tube will therefore arrest them, and transform them into X-rays. Even if a small

quantity of cathode rays should traverse the wall of the focus-tube, they would be too feeble to have any effect on the skin.

The supposed action of ultra-violet rays has been evoked to account for the phenomenon. This theory was held by *Bowles*, *Stenbeck*, *Elliot*, and others.

It is probable, says *Freund*, that the phosphorescent glow set up by the impact of the cathode rays does give off a certain number of ultra-violet rays. Certain resemblances between the effects of X-rays and those of ultra-violet light seem to support this hypothesis. Several authors have reported curious cutaneous accidents due to insolation. One of the most interesting is related by *Professor Lannelongue*. 'At the Enfants-Malades several children showed signs of burning on those parts of their person not protected by clothes. The children were well shielded from direct sunshine, their playground being a small court which was only exposed to the sun from above. Investigation proved that the accidental scorching was due to reverberation of the sun's rays by the sand. On screening off these by means of strontium glass the attacks of sunstroke were avoided.' These phenomena were due to the ultra-violet rays of light, and it seemed at first only natural to attribute the analogous effects of X-rays to the same cause. Though the primary action is somewhat similar to that of the ultra-violet rays, it is not identical, the further evolution of the skin lesion being quite different.

Moreover, although ultra-violet rays are produced in the tube, they cannot act on the skin without traversing the glass. Now, it is well known that ordinary glass absorbs these rays almost entirely. Crown-glass is the only variety that permits their passage in any quantity. For this reason the lenses of phototherapeutic lamps are usually made of quartz. Substances which arrest the ultra-violet rays are quite permeable to X-rays. An observation of *Möller* is perfectly conclusive on this point. He was treating a patient for lupus vulgaris of the face. The chest showed signs of reaction, though it was protected by a black dress and a red under-bodice. *Möller* concludes from this that ultra-violet rays are not arrested by the clothes, whereas it would be much more reasonable to suppose that the reaction in this case was due to X-rays.

Tesla thinks the occurrence of dermatitis is due to the disintegration of the electrodes, and *Crookes* asserts that metallic particles

are projected from the cathode during the passage of a current. The coloration of the walls of the tube seems to confirm this hypothesis. Careful experiment however shows that there is no appreciable loss of weight in the electrodes, even after prolonged use. It is the interior surface of the tube which becomes coloured, and it is difficult to understand how metallic particles can traverse the thickness of the glass, which they must necessarily do before they could affect the tissues. Moreover, the presence of metallic particles in the skin has never been demonstrated. The histological researches of *Gilchrist* on this point gave absolutely negative results. Finally *Oudin* studied this metallic bombardment, and found that even when the skin was strongly tattooed by the metallic particles, no irritation of the skin occurred such as is produced by the X-rays.

These hypotheses did not long survive. In 1897 and 1898 *Gilchrist* refuted them one by one. To-day they are abandoned, and we have only alluded to them in order to prove their futility.

Two hypotheses remain, each of them of great importance—viz., that the action is due to the Roentgen rays themselves, and that it is due to the electric discharges or effleuves issuing from the focus-tube.

From 1897 to 1903 this question has been freely discussed, and the publications on the subject are innumerable. Physicians in Germany, Vienna, and France, have taken part in the discussion, and some authors have at different times supported totally opposite theories. Thus *Freund* at first maintained that the active agent was the X-rays themselves; more recently he denied this, whereas at the present time he says, 'The therapeutic action is due to both causes—the X-rays and the electric discharges.'

Around a focus-tube in action there is an oscillating electrostatic field, the intensity of which varies with the resistance of the tube A neighbouring body will be influenced by this field only if situated close to the tube, for the oscillations are damped down at a very short distance from it. *Kord* has proved the existence of an oscillating and alternating magnetic field around a Crookes tube, while according to *d'Arsonval* this alternating magnetic field produces profound perturbations in the organic tissues which it traverses.

It is of the highest importance to determine whether the Roentgen rays themselves produce therapeutic effects, or whether

these are due to electrical discharges and oscillations set up by tubes of high vacuum.

Hawkes as early as 1896 attributed the occurrence of burning to the X-rays themselves. *Kümmel*, *Rieder*, *Albers-Schoenberg*, *Cowl*, *Forster*, *Jutassy*, and *Rollins*, were of the same opinion, as were also *Schiff* and *Freund* up to 1898. In their opinion no cutaneous reaction resulted as long as the tube did not emit X-rays. *Sträters* also made several communications on this subject.

In the opposing camp in the early days we find *Oudin*, *Barthélemy*, and *Darier*; they were joined later on by *Foveau de Courmelles*, *Balthazard*, *Destot*, *Scholl*, *Leonard*, *Tarchanoff*, *Bordier*, and *Salvador*, and ultimately, in 1899, by *Schiff* and *Freund*.

This second hypothesis was long the preponderating one. In France *Oudin*, *Barthélemy*, and *Darier* considered that the active rôle was played by the oscillating magnetic and electro-static fields surrounding the focus-tube. Up to 1900 one may say that this explanation was the one generally received. At that date *Kienböck* thus expressed himself: 'At the present day it is the usual practice in radiotherapy to use hard tubes, which have become useless for radioscopic purposes. The procedure has the support of *Gocht*, *Gassmann*, *Schenkel*, *Schiff*, and *Freund*, so that a student guided by the instructions in vogue would infallibly use hard tubes in radiotherapy.'

It was as a result of a remarkable series of experiments, performed by him in 1900, that Kienböck was led to the opinion that the sole active agency was the X-rays themselves, and that the influence of the electric effleuves was nil. It may be of interest to examine his investigations, and see what arguments he used against the supporters of the opposite hypothesis. He began his investigation in consequence of a series of accidental cases of radiodermatitis, which, as they present some features of unusual interest, we give in his own words:

'From November, 1899, to March, 1900, I had been treating four cases of skin disease in the face. I was using a focus-tube made by *Reiniger*, *Gebbert*, and *Schall*, which had previously caused complete alopecia in a case of sycosis after thirty-seven exposures. Eac patient was irradiated daily, and I purposed to continue the treatment until reaction appeared. The séances were of fifteen minutes' duration, with a distance of 6 to 10 inches between the anticathode and the skin. The induction-coil gave an 18-inch spark, and was

driven by a continuous current from the public mains, with a pressure of 110 volts. A turbine mercury break was used. The secondary current had an equivalent spark-gap of at least 12 inches. At the beginning of the treatment the tube had a high resistance, and produced but slight desquamation, and that slowly. As the tube became harder it produced less and less X-rays, but the electrical discharges were increased. On March 17 three cases had undergone their eightieth exposure, and, quite discouraged, I was about to abandon the treatment.

'At this juncture a spark pierced the tube, and rendered it useless. On March 18 I employed a new focus-tube. This was an automatic regulating tube, made by Müller, which gave a good steady light, the X-rays being of great intensity; and, as it was a soft tube, it gave but few electric effleuves outside the tube. On March 18 the four old cases and one new one were rayed with this new tube.

'Soon afterwards, from March 29 to April 3, all five patients showed signs of inflammation. Day after day the treatment had to be suspended. During the two succeeding weeks the reaction increased, resulting in exfoliation and ulcerations. Thus in lieu of the long course of treatment which I was expecting, all of these cases were attacked by serious dermatitis within a fortnight after the first irradiation by a soft tube.'

This observation proves conclusively that a hard tube, emitting strong electrical discharges and X-rays of great penetration, is almost without therapeutic action, whereas a soft tube possesses the therapeutic qualities in a high degree.

The old method, which was to continue the exposures until reaction set in, was faulty in theory, and most dangerous in practice. So long as the active agent remained unrecognised it was manifestly impossible to guard against its ill effects.

This series of accidents put *Kienböck* on the right track. He recognised the fact that the X-rays themselves are the true therapeutic agents, to the exclusion of every other force, and his further experiments only confirmed him in this opinion.

'In April, 1900,' he says, 'I was treating a young girl suffering from favus, by epilation of the scalp. The right side of the head was irradiated on three occasions with a soft tube, while the left side of the head was irradiated in a similar manner with a hard tube giving the same quantity of rays, but of greater penetration.

After two weeks' interval all the hairs on the right side of the head fell out, whereas on the left side only a very imperfect epilation resulted after some further delay.

'Another experiment shows the same result. The right side of a rabbit was exposed to a hard tube, which gave out very few X-rays, but strong electrical effleuves, while at the same time the left side was exposed to a soft tube. The result was as I had expected : the hard tube did not produce any loss of hair, whereas the soft tube set up a dermatitis followed by extensive alopecia.'

The arm of a patient was exposed for one hour to the radiations from a soft tube, a plate of lead with a circular aperture being interposed between the tube and the skin, but without touching the latter. After the lapse of several weeks a dermatitis occurred, which was limited to an area corresponding to the aperture in the lead plate.

The experiment was repeated on the opposite arm, the lead shield being replaced by a small rectangular plaque 2 centimetres in breadth. A dermatitis resulted over an extensive surface of the skin, except at the spot which was shielded by the little plaque of lead.

In both these cases the lesions were confined to the regions actually exposed to the impact of the X-rays.

If the focus-tube is adjusted so that the plane of the anticathode is perpendicular to the surface of the skin, dermatitis is produced only on the side adjacent to the luminous hemisphere of the tube. Behind the anticathode the tube is dark, and the corresponding area of the skin is not affected. The two regions are sharply divided by a line corresponding to the plane of the anticathode. We cannot suppose that the electric effleuves are bounded by this line, since they issue equally from the whole surface of the tube, whereas the dermatitis is strictly limited to the part irradiated by the Roentgen rays.

This experiment seems quite conclusive. The electro-static field extends symmetrically all round the tube, and consists of concentric oscillations which are propagated equally in all directions. If the dermatitis were set up by these electric oscillations, it could not possibly be confined to one side of the tube. We do not in any way deny the existence of electrical discharges from the focus-tube, which would be propagated in straight lines, like the effleuves from a static machine. Such effleuves from a tube in close proximity to

the skin would strike the nearer portions of the skin at right angles, and should be visible. In no case, however, would they be able to penetrate a metallic shield which was properly earthed.

Another possible explanation was the supposed existence of other radiations accompanying the X-rays, issuing from the same point, and having the same intensity. This is too complicated a hypothesis, demanding the complete analysis of all radiations emitted from a focus-tube—an analysis which, in the present state of our knowledge, is quite impossible.

Kienböck is in complete agreement with *Sträter's* dictum: 'Soft tubes are active, hard tubes very slightly so.'

Kienböck sums up the arguments of his opponents, more particularly those of *Schiff* and *Freund*, and we cannot do better than quote his words:

'Those who believe that the therapeutic agent is of the nature of an electrical discharge base their hypothesis on the following arguments:

'1. The skin reaction is prevented by the interposition of a thin plate of aluminium, or even paper or silk, provided that these are earthed. This is thought to be due to the interception of the electrical charges which are led to earth, while the X-rays, which alone reach the skin, are incapable of setting up reaction.

'This observation is inaccurate, for if a very penetrating tube is employed reaction will occur. *Cowl* exposed one of his eyes to the rays for a quarter of an hour, and set up a violent inflammation of the lids, which lasted more than a week.

This occurred notwithstanding the interposition of a thin plate of aluminium, which would have completely warded off the electrical effleuves.

'2. The second argument is the supposed absence of reaction when the focus-tube is driven by a static machine. It is supposed that only large induction-coils produce sufficient electrical tension to cause these accidents.

'To this it may be said that it is only with large coils that we get a sufficient quantity of X-rays, with the necessary power of penetration.

'3. Another point is the irritation which sometimes occurs when the tube is brought too near the skin. It is supposed that the electrical effleuves from the tube pass to the skin. The real explana-

tion is that the nearer the tube, the greater the number of rays received by the skin. Like all ethereal vibrations, the X-rays follow the law of inverse squares.

'4. A final argument is that in radiography accidental inflammations mostly follow the use of hard tubes. It should be remembered however, that these accidents usually occur when dealing with parts of some considerable thickness, requiring great penetration of the rays, and therefore the use of hard tubes. Possibly the first attempt may not be successful in consequence of the rays being too penetrating, and the tube is brought nearer and nearer to the patient. At each essay the time and intensity of the exposure is increased. If the tube becomes heated it will become softer, and may then readily set up cutaneous reaction. This, however, is due to the rays, and not to the electric effleuves. If the tubes in the first instance had emitted rays of the required penetration, there would not have been any necessity for modifying the current or increasing the duration of exposure.'

It is well known that at one time *Freund* maintained the exclusive action of the electric discharges in radiotherapy. In support of this view, he made some experiments which at first sight seemed conclusive.

He showed a guinea-pig which on eight occasions had been exposed to negative electrical discharges. As a result there was on the flank which had been treated a small circumscribed bald patch, the skin of which had a perfectly normal appearance.

Kienböck, who examined the animal, thus criticises the experiment: 'It is remarkable that such a reaction should have appeared only fifteen days after treatment. Moreover, the defined outline of the alopecia and the absence of acute dermatitis renders it probable that there was some misapprehension of the result. Probably attempts were made after each séance to see if the hairs were loosened, and in this way some may have been removed without any evidence of pain on the part of the animal.'

Independently of *Kienböck*, *Oudin* made some interesting studies on the nature of the active agent, in France. At first he thought the electrical discharges were the most important factor. Later he was much impressed by the injurious results of soft tubes, and asserted categorically: 'Electricity has no influence whatever on the occurrence of Roentgen dermatitis.'

Oudin interposed screens of insulating material, such as celluloid

and ebonite, between the skin and the tube. He found that the reaction was not diminished. These bodies are transparent to the X-rays, but are non-conductors of the electrical discharge. It may be objected that they do not entirely stop the electrical discharge, since they would act as condensers. A plate of glass however, which also acts as a condenser, prevents the occurrence of erythema, in consequence of its opacity to the X-rays.

A crucial experiment shows that the intensity of the cutaneous lesion is proportional to the transparency to the X-rays of the metal employed. We will quote it verbatim :

'We constructed a metal shield by riveting side by side a thin plate of aluminium and one of lead, each 8 centimetres square and of the same thickness. They formed a perfectly continuous electrical shield, and it could hardly be supposed that electrical discharges would affect one half of the shield more than the other. We tested this by means of a gold-leaf electroscope, and also with a Lippmann's capillary electrometer—an instrument of exquisite sensibility. When the screen was duly earthed and interposed between a source of electricity and the electroscope, not the slightest action on the gold leaves or on the column of mercury could be detected. The result was the same whether we used the effleuve of a static machine or a high-frequency resonator, or even a Roentgen tube in absolute contact with the plates. This proved that the screen was absolutely impenetrable to electric discharges. Now, if such a screen be interposed between the tube and the skin, it will be found that only the area of skin opposite the leaden half will be shielded from the X-rays. If we take a rabbit and irradiate the flank for half an hour, epilation will occur after the lapse of a fortnight, followed by an acute dermatitis. If the composite aluminium and lead screen has been interposed between the tube and the skin, the epilation and subsequent dermatitis will occur only beneath the aluminium half of the screen, the lead having absolutely protected the corresponding area from any lesion whatever. This protective action usually extends slightly beyond the limits of the lead screen. In one such experiment, a fortnight after exposure the whole side of the animal was inflamed, red, and discharging, with the exception of a surface of healthy skin, absolutely defined, 8 centimetres square, which corresponded exactly to the projection of the lead screen.'

In consequence of these demonstrations, most of the partisans of

the electrical hypothesis went over to the opposite camp. Even *Schiff* and *Freund* modified their opinion.

In his report to the Congress of Dermatology at Vienna in 1901, *Schiff* gave it as his opinion that soft tubes were theoretically the more active; on the other hand, in radiotherapy equally good results were obtained by hard tubes, by the use of which the dosage was rendered easier and accidents were more easily avoided.

At this time *Freund* admitted that the X-rays themselves played a certain part in radiotherapy, but were not capable of producing cutaneous reaction without the presence of other factors, such as electric waves and electric discharges, which he still considered to be the most potent agents in the production of reaction.

Scholtz took up once more the study of this important question, which had not been finally set at rest by the labours of *Kienböck* and *Oudin*. In a work published in 1902 he detailed a series of experimental researches, of which we give a résumé, since they are the most recent on the subject and prove indisputably the exclusive rôle of the X-rays.

Scholtz's first experiments were made on rabbits and guinea-pigs. In the later experiments, however, he used young pigs, since their skin more nearly resembles the human skin in its structure. Moreover, in these animals the modifications due to X-rays—alopecia, ulceration, etc.—closely resemble those produced in the human subject, and that not only in their form and evolution, but also in their period of latency.

Scholtz's first task was to determine the different effects produced by a hard and a soft tube.

The subject of experiment was a young pig, which was irradiated on either flank over a surface the size of a five-shilling piece. On the right side a soft tube was used, on the left side a hard tube. From February 9 to 27, 1901, seventeen exposures were made, the tube being at a distance of 6 inches. During the whole series of exposures the same tubes were used with the same current, the vacuum only varying on the two sides.

On February 27, on the right side the hairs began to fall off freely. There was no apparent change on the left side.

On March 3 on the right side all the hairs had fallen off, the epithelium was raised in phlyctenulæ, and the whole region was scaly and weeping. On the left side a slight alopecia had commenced.

On March 9 the skin on the right side was necrosed and covered with a diphtheroid membrane, and the subjacent tissues were infiltrated. There was a well-marked line of demarcation between the area exposed and the adjacent skin, which had been protected by a metallic shield. On the left side all the hairs had fallen out, and the skin had a slightly atrophic appearance.

On the right side during the two succeeding weeks the necrosis increased, and a deep slough appeared. This extended down to the muscular layer, and only healed after many months. On the left side the irradiated spot remained bare of hair, but without any trace of necrosis.

In another experiment, following *Steinböck's* example, *Scholtz* adjusted the focus-tube so that the plane of the anticathode was perpendicular to the skin. A line drawn with nitrate of silver marked the boundary between the irradiated area and that which was behind the anticathode. The reaction occurred only on the side which was irradiated by the X-rays.

'These experiments,' says *Scholtz*, 'give precisely the same results as those of *Kienböck*, and demonstrate clearly that radiodermatitis is attributable to the X-rays themselves.

'In order to remove any possible doubt, I made the following experiment:

'A young pig was taken, and a circular surface some 8 inches in diameter was marked out on the back. This was divided into five segments.

'The first segment was covered by a sheet of lead one-fourth of a millimetre in thickness; the second by a plate of glass half a centimetre thick; the third by a sheet of aluminium half a millimetre in thickness; the fourth by three thicknesses of black paper; the fifth segment was left bare.

'The whole region was exposed to the X-rays for forty-five minutes, at a distance of 8 inches.

'After an interval of ten days the hairs were beginning to fall out from the skin of the fifth sector—*i.e.*, the one that was left bare. A similar condition appeared on the fourth sector, that covered by black paper. There was no apparent modification of the skin of the other sectors.

'After three weeks a superficial necrosis appeared on the skin of the fourth and fifth sectors. On the third sector—that covered by aluminium—the hairs were less numerous, and easily pulled

out. On the two other sectors—those shielded by lead and glass respectively—no reaction appeared.

'This experiment was repeated on several occasions, with the same result. Similar results were obtained on the human skin in two cases of favus which were being treated by epilation. In this instance the black paper on one of the sectors was replaced by a mercurial plaster. The mercurial plaster proved more opaque to the X-rays than the aluminium plate. This exactly corresponds with the intensity of the shadows cast on a phosphorescent screen by the two bodies.'

Scholtz comes to the following conclusions, which we reproduce in their entirety: 'The greater the quantity of the X-rays emitted by the tube, the greater is the intensity of its effect on the skin. It is, therefore, preferable in most cases to use soft tubes in the practice of radiotherapy.

'The effect on the skin may be modified at will by altering the current intensity, the distance of the tube, and the duration of the exposure.

'The more perfectly a substance arrests the passage of X-rays, the more perfectly it shields the skin from the active rays which affect it. Black paper interposed in the course of the X-rays gives no trace of shadow on the fluorescent screen or on the photographic plate. Consequently, as it allows the X-rays to pass freely, it cannot protect the skin from dermatitis.

'The pale-gray shadow on the fluorescent screen thrown by a thin plate of aluminium is rather feebler than that of a mercurial plaster. This corresponds to the respective degrees in which they protect the skin from the injurious action of the rays.

'Thin sheets of lead and thick sheets of glass are impermeable to X-rays, and, in consequence, completely protect the skin against their action. Bodies which, like aluminium, cast but a feeble shadow on the fluorescent screen, nevertheless exercise a considerable influence in arresting the more active rays.

'This proves that it is precisely those rays which are least penetrating which are most active in causing reaction.

'Once again these experiments show clearly that it is the Roentgen rays themselves which constitute the active agency in radiotherapy.'

Clinical observation is in perfect accordance with this theory. Practitioners who employ hard tubes are obliged to give an

extended series of exposures, each one of comparatively long duration. Thus to produce an epilation, *Schiff* and *Freund* give ten, fifteen, or twenty exposures, each of a duration of ten to thirty minutes, whereas with a soft tube epilation may be effected in a single séance of no great length.

At the present day it is very rare to find any serious opposition to the view that the X-rays are the sole agency used in radiotherapeutics.

If there were any possibility of doubt on the subject, it would be removed by a consideration of the cutaneous reaction caused by radio-active substances. *Becquerel* and *M.* and *Mme. Curie*, by placing tubes containing radium in contact with the skin, produced on themselves lesions analogous to those caused by a Roentgen tube.

Oudin, who examined the actino-dermatitis produced in this manner, considered it to be absolutely analogous to radiodermatitis. *Walkhoff* and *Giesel* have made similar observations.

In these cases of actino-dermatitis there can be no question of electrical discharges. X-rays, or some similar radiations emitted by the radio-active substances, must be regarded as the sole cause originating the cutaneous reaction.

As *Oudin* points out, even admitting that the action is due to the projection of negatively-charged particles torn from the atom, the electric charge must be quite insignificant in comparison with the oscillations round a focus-tube, however enormous they may appear in comparison with the mass of the corpuscles that carry them.

We ourselves, in the course of our practice of radiotherapy, have had occasion to repeat some of the foregoing experiments, and our investigations have completely confirmed those of *Kienböck*, *Oudin*, and *Scholtz*. Our results may be thus expressed:

'The Roentgen rays themselves constitute the active agency in radiotherapy, to the exclusion of the electrical discharges and other phenomena which are present in the neighbourhood of a focus-tube in action.'

CHAPTER III

BIOLOGICAL EFFECTS OF THE ROENTGEN RAYS

1. *The Action of X-Rays on Cutaneous Tissues and on Internal Organs.*

At an early period in the application of Roentgen rays it was noticed that signs of reaction were mainly restricted to the skin. In slight lesions the superficial layers of the dermis alone were attacked; when ulceration supervened, the whole thickness of the skin was first destroyed, and subsequently the subcutaneous tissues became affected. Very soon, however, a much wider sphere of action was attributed to the X-rays. They affected, it was said, not only the skin, but muscular tissues, deep-seated vessels and internal organs, the nervous system, and the general health.

We need only glance at the publications of the last few years to find the Roentgen rays prescribed again and again as a universal panacea. They act on every organ of the body, and cure lesions of the most varied character. This is the outcome of an ignorant infatuation and a total absence of technical knowledge.

It will be of interest to inquire what are the tissues most affected by the X-rays, and to examine the alterations, both general and microscopic, which these tissues undergo. We will confine our attention to the effect of the rays on healthy tissue.

It is important to determine whether the action of the rays is limited to the portion of the skin actually irradiated, or whether it extends to the surrounding area and to the subjacent tissues. Roentgen dermatitis is generally limited superficially to the area on which the rays impinge. If a lead screen with an aperture be used, the skin, even when acutely inflamed, is unaffected except in the exposed spot. The line of demarcation between the dermatitis and the healthy skin exactly coincides with the edge of the aperture in the protecting shield.

Similarly in radiotherapeutic treatment the reactionary erythema appears only over a surface which corresponds exactly to the aperture in the protecting lead.

It has been found that the X-rays set up reaction, not only at the point where they impinge on the surface, but also at the place of exit whence they leave the body. In other words, there will be a modification of the cutaneous tissues at a point diametrically opposite the point of incidence of the rays. Observations by *Revillet*, *Kümmel*, and others corroborate this occurrence of reaction at the point of exit. These observers subjected the thorax of a patient to an intense exposure with very penetrating rays, which resulted in the production of erythema and ulceration of the skin, not only on the chest, where the rays impinged, but also on the back at the point where the rays issued after traversing the body. *Kienböck*, experimenting on a pigeon, obtained analogous results. The bird was placed in a cardboard box, and its back was exposed to the action of the rays. The feathers fell out, not only on the back, but also on the breast at a point diametrically opposite to that irradiated. No ulceration resulted on the back of the bird, and the condition of the intestinal organs was but little, if at all, affected. New feathers grew much more quickly on the breast than on the back, as might indeed have been expected.

Kienböck concludes: 'The Roentgen rays not only act on the surface on which they fall, but, after having penetrated the body, they act in a similar manner on the opposite side at the point of exit.'

This result may be partially explained when we consider the small mass of a bird's body, which contains a considerable quantity of air. Rays of medium penetration pass through the body with but little absorption, and may thus produce on the skin at the point of exit changes analogous to though less marked than those which were caused at the point of entrance.

It is, however, to *Scholtz* that we owe the complete elucidation of this phenomenon. His experiments were conducted on rabbits. The inner surfaces of the two ears were placed in contact and fixed to the animal's back. After exposure to the rays the hair fell out from the whole of the outer side of both ears and also from the back. No necrosis of the cartilage of the ears followed. The experiments were repeated on a pig, with similar results.

The ear was pulled backwards and fastened to the neck of the

pig, and the animal was exposed daily to an irradiation of moderate intensity, the neighbouring regions being protected by a lead screen. Ten days after the last exposure, the hair began to fall out, depilation commencing on the outer side of the ear, then on the inner side, and finally spreading to the corresponding portion of the neck. On the outer side of the ear phlyctenulæ appeared, followed by a serous discharge and slight ulceration. On the inner side of the ear and on the neck similar lesions appeared several days later, but they were much less severe in character. No necrosis of the cartilage occurred, and on healing the ear resumed its normal appearance.

Scholtz comes to the following conclusions: 'The X-rays act chiefly on the skin, the deeper tissues, muscle, cartilage, and bone being but slightly affected. The necrosis of these tissues is secondary and due to the intense inflammation and ulceration of the skin.

'The Roentgen rays act on the skin at the point where they first penetrate it; but they may also affect it at the point of emergence, after having traversed layers of cartilage or muscle of some thickness.'

These conclusions are in complete agreement with the theory and practice of radiotherapy. When the rays are not of great penetration they are almost entirely absorbed by the skin on which they fall, where this is of sufficient thickness. Where the skin is very thin the less penetrating rays will still be absorbed, but those which are more penetrating will pass on in a straight course to the opposite side of the body. If in their course they meet other tissues more dense than the skin, they will be absorbed without causing any reaction at the point of exit. They may, however, pass through the internal tissues with only a slight decrease of intensity, and on emergence they will then exhibit phenomena analogous to those which they caused at the point of entry. The difference will be merely one of degree.

The rays of the highest degree of penetration will pass through the tissues without marked action either at the point of entrance or of exit.

It is difficult to understand how the X-rays can have sufficient penetration to traverse the thorax of a healthy subject and still retain sufficient intensity to produce ulceration at the point of exit. In the case reported by Kümmel the patient was tuberculous and very emaciated, and this may in some degree explain the result.

Some authorities believe that they can obtain deep-seated reaction without any effect on the superficial tissues.

This statement must be received with caution. *Kienböck* says: 'I find it hard to believe that deep-seated modifications can be attained without the occurrence of dermatitis at the point of entry of the X-rays. Most probably an ulcer would be formed at the point of incidence of rays of sufficient intensity to modify the deeper tissues. The curative action of X-rays on morbid foci in internal organs is most uncertain.'

We agree with *Kienböck* in this opinion. In the normal subject it is difficult to admit the occurrence of deep-seated action without any accompanying reaction of the integument, for it is the skin which most readily reacts to the X-rays. When, however, we come to deal with abnormal elements in the tissues the case is somewhat altered. It is possible that the rays have a selective affinity for abnormal tissues, such as epithelial and sarcomatous neoplasms, and that these are more easily affected than the skin. Even then the difference in sensibility would hardly be sufficient to prevent a sharp reaction on the surface. It is this fear of radio-dermatitis that limits the amount of radiation permissible in any given case, and in our experience we have always met with a more or less vivid reaction of the skin, even when we have taken the precaution of covering it with a thin sheet of aluminium foil, so as to cut off the less penetrating rays. It is not probable that there would be less reaction of the skin when the deeper tissues are irradiated.

Action of X-rays on Internal Organs.

As we know that a portion of the Roentgen rays is arrested by the internal organs, while another portion passes through, it is natural to inquire whether these have any specific action on them. When the surface of the abdomen is exposed to the rays, it is important to know what influence is exerted on the intestines and other abdominal organs. In this situation there is no osseous skeleton to arrest the rays, nor is there much protection to the head of a child, since the osseous tissue there is very thin.

The answer to this question involves numerous practical considerations. If the X-rays are able to produce in the intestines lesions similar to those which arise in the skin, the greatest degree

of caution must be used in treating those regions where the internal organs are not protected by bones as well as by muscles and skin.

Similarly, if paralytic and other phenomena may follow irradiation of the brain and spinal cord, we should be very loth to treat the head of an infant by radiotherapy.

At first sight it appears reasonable to suppose that X-rays may exert a modifying influence on internal organs. The cure of certain tumours of splanchnic origin may be explained by the selective action of the rays on abnormal tissue. In *Oudin's* work, however, we find instances of effects which may be termed general, such as attacks of vomiting and loss of appetite. *Scholtz* considers these symptoms to be due to psychic causes, since no post-mortem lesions have been discovered. Moreover, the rapidity with which these symptoms disappear prove that the lesion, even if it existed, was of the slightest description.

At the twelfth Congress of the American Electrotherapeutic Association *Dickson* reported several cases of severe diarrhœa, while *Nann* of Savannah had seen constipation follow the use of the Roentgen rays.

At the Congress of Grenoble in 1904 *Albert Weil* reported some cases of constipation cured by X-rays. He exposed a limited part of the surface of the abdomen to the rays, using the maximum dose that the skin could absorb without injury—4 H. to 4½ H. in Holzknecht's units; the rays had a penetration of No. 6 or No. 7 on Benoist's radiochromometer.

The effect on the intestines appeared to be constant. The rays had a sedative effect, allaying spasmodic action, and causing healthy evacuation of the bowels in patients who had resisted all other methods of treatment. These facts are of great interest, and further experiments on the subject are to be desired.

Action on the Nervous System.

A special influence on the nervous system has been attributed to the X-rays. They were said to give rise to various disturbances—paraplegia, paralysis, abortion, etc.

In the case of small animals *Rodin* and *Bertin* found that the X-rays caused paralysis and cramp, in addition to the usual cutaneous lesions. In the case of animals exposed for too long a period to the action of the rays death usually occurred in from eight to

fourteen days. They found signs of meningo-myelitis in the regions of the cord corresponding to the cutaneous areas which had been over-exposed. They observed thickening and adherence of the meninges, medullary congestion, cellular hyperplasia, and even hæmorrhagic foci of limited extent. This meningo-myelitis was not of septic origin, the bacteriological examination of the blood, of the cord, and of the cephalo-rachidean fluid yielding negative results.

Jutassy observed paresis of the extremities, followed by death, in the case of rabbits irradiated by Roentgen rays. *Oudin*, *Barthélemy*, *Darier*, *Mdlle. Ogus*, and others, have also reported cases of paraplegia in small animals.

Kienböck has seen similar phenomena in mice, but guinea-pigs are not sensibly affected.

Scholtz made experiments on rabbits and mice, using young animals in whom the fontanelles were still widely open. In only one out of five animals were there any symptoms of paralysis after an hour's irradiation, nor could any pathological lesion be detected after death. He concludes that X-rays do not affect the brain or spinal cord.

In 1902 *Jicinsky*, experimenting with guinea-pigs, determined the presence of degeneration in the white matter, and also in the posterior cornua of the cord. This, however, was after severe burning of the skin in the region of the vertebral column.

Danysz has reported lesions of the nervous system following exposure to the radiations of radio-active substances.

In many of these cases it is doubtful whether the paralysis was really due to the X-rays. It usually followed a very severe exposure, and the resulting meningo-myelitis was possibly due to some septic infection of the inflamed surface.

According to the observations of *Danysz*, *Rodet*, and *Bertin*, it seems proved that the rays have a specific action on the nervous system. It must not, however, be supposed that such results can be obtained on the human subject under ordinary conditions. Hitherto observations have been made on small animals only, and there is little analogy between the action of the rays on these and on the human subject. In order to get any results whatever on the nervous system, very considerable doses are necessary, and these are of sufficient intensity to produce serious ulceration of the skin. The nervous system of these small animals is but slightly protected

from the action of the rays, in consequence of the thinness of the cranium and vertebral arches. In man these bones are of sufficient thickness to arrest the radiations almost completely.

In the human subject also, the distance of the central nervous system from the point of application is usually sufficient to guard it from any injurious effects from irradiation.

On the other hand, there can be no doubt about the sedative action of the Roentgen rays on pain. Again and again neuritis and neuralgia have been ameliorated and cured by a few exposures.

Hence we must concede that the X-rays have at all events a local action on the peripheral nervous system—an action which in most cases is of an anodyne nature.

Testicle.—Some interesting experiments have been recently communicated to the *Münchener Medicinische Wochenschrift* by *Albers-Schoenberg* and *Frieben*, which seem to show that the X-rays have a specific action on the reproductive organs.

The experiments were carried out on male guinea-pigs, which were on several occasions exposed to an irradiation of moderate amount. They were then mated with females which had not been submitted to the action of the rays. Although they were kept together for periods ranging from fifteen days to five months, not one of these females produced offspring. By moderate exposure to X-rays the male guinea-pigs were not affected in their general health, and retained their sexual appetite and powers of copulation. Animals which were kept under similar conditions as a control experiment retained their fecundity.

After death the cause of this sterility was revealed. In the case of all the animals which had been irradiated the testicles were found atrophied, their size being diminished to one-half, or even one-third, of their normal volume. Microscopical examination showed that the cells lining the seminiferous tubules had disappeared, and were in certain localities replaced by small retracted cells with signs of protoplasmic degeneration. Spermatoblasts were nowhere to be found, nor any appearance of spermato-genesis. An examination of the contents of the vesiculæ seminales also disclosed the complete absence of spermatozoa.

The sterility is apparently due to a condition of necrospermia, which after some time passes on to complete azoöspermia. We should therefore proceed with great caution when treating the inguinal or scrotal regions by radiotherapy.

On the other hand, it is not irrational to suppose that careful and moderate irradiation might have a stimulating action on the secretion of semen. It has been shown that the bio-activity of certain cells is stimulated by slight exposure to the X-rays, whereas these same cells are withered and destroyed by a longer exposure.

Uterus and Liver.—According to some observers, Roentgen rays may exercise some influence on the course of gestation. In experiments on small animals the rays have been found to cause abortion.

As a result of experiments on dogs, *Lépine* and *Boulud* have proved that the liver, after irradiation, contains less glycogen and more sugar than before, whereas the total amount of the two combined is diminished. The primary effect of irradiation is therefore to stimulate both glycogenesis and glycolysis. After the liver has been irradiated for an hour or more, the conditions are reversed: both glycogenesis and glycolysis are diminished. It will be interesting to learn if the results of the action of X-rays on the isolated liver are confirmed when the experiment is repeated on the organ *in situ.*

Spleen and Lymphoid Tissues.—*Heinecke* has shown that irradiation by the X-rays causes the destruction of the Malpighian corpuscles of the spleen, with accompanying accumulation of pigment and decrease of the cellular elements in the splenic pulp. On studying these lesions further, two distinct processes may be distinguished. The one, which attacks the pulp and causes pigmentation by decomposing the hematin of the blood, follows some days after a prolonged irradiation of small animals. The other, which destroys the Malpighian corpuscles, sets in early, after even a short exposure, in animals of any size. This destructive action may be observed not only in the skin, but in all organs containing lymphoid tissue.

Heinecke has carried out a series of experiments on rats, guinea-pigs, and dogs. If the animal be killed two hours after a short exposure, well-marked alteration is found in the Malpighian corpuscles of the spleen, as well as in the lymphatic glands and follicles of the intestines.

In the Malpighian corpuscles, for example, spherical grains of chromatin may be found irregularly disseminated in the tissue. These grains, of various size, are evidently formed from the débris of cellular nuclei. Alongside of these, transparent areas appear in

which the lymphocytes have in a great measure disappeared, to be replaced by large cells of an epithelioid nature. If the animal is killed two hours later—*i.e.*, four hours after the irradiation—the free chromatin granules have entirely disappeared. They have been absorbed by phagocytes, enormous cells which are literally laden with chromatin granules. These phagocytes are found principally in the zone occupied by the epithelioid cells already mentioned. They do not however, remain long in this situation. After a certain time they leave the follicle, so that at the end of twenty-four to thirty-six hours there is no trace of them remaining. At the same time the lymphocytes, the specific elements of the Malpighian follicle, are in great measure destroyed, the extent of this destruction depending on the intensity of the previous irradiation. The destruction is however not complete, for in animals killed after an interval of eight to fifteen days the lesions have been already repaired, and the Malpighian follicle has been regenerated.

Similar lesions—*i.e.*, destruction of lymphocytes and phagocytosis of their nuclei, are found in other lymphoid tissues—in lymphatic glands, in the intestinal lymphatic follicles, in the thymus, and even in the marrow of the long bones. In these organs also a considerable portion of the specific elements of the tissue disappears, and is replaced by fat cells.

A similar experiment was made by the author on a dog of medium size, in which the abdomen was irradiated. In the Malpighian follicles of the spleen and in the lymphatic glands of the mesentery intestine, there was evidence of considerable destruction of the cellular nuclei. This destruction was noticeable long before any action on the epithelium was visible. If these observations are confirmed, they will afford a solid basis for the employment of X-rays in visceral affections. In the author's opinion, these experiments point to the possibility of treating hæmatopoietic diseases by means of radiotherapy.

Clinical experience is in advance of theory in this matter. Already numerous cases have been reported of leukæmia, lymphadenoma, lymphosarcoma, and mycosis fungoides, which have been modified by treatment with the Roentgen rays. It only remains to be seen if the results obtained are durable.

Eye.—There is one organ which would seem to be specially exposed to injury if not properly protected during an X-ray séance.

Authors are, however, not agreed as to the manner in which the eye reacts to the X-rays. Some believe it to be exceedingly sensitive and very easily affected, while others maintain that it shows little reaction even to intense exposures.

By exposing the eye of a rabbit to the X-rays, *Chalupecky* obtained an acute inflammation, followed by suppuration. The eye was destroyed, as if it had been burnt with ammonia. Similar results have been reported by other experimenters.

The lesions of the eye caused by X-rays resemble those set up by ultra-violet rays, as described by *Widmark* in his investigations on snow blindness and the effects of the electric arc. On the other hand, *Scholtz* entirely failed to produce either inflammation of the interior of the eye or even disturbance of vision, notwithstanding the fact that the exposure was made on the wide-opened eye, and was of sufficient intensity to produce sloughing of the eyelid.

In a discussion of the American Electrotherapeutic Society frequent mention was made of the injurious effect of the X-rays on the eyes. In one of the cases reported the reaction was so severe as to cause complete blindness.

It should be remembered that in all the cases of injury to the eyes which have been reported, it is the operator and not the patient, that suffers. This occurs principally to those who practise radioscopy, and is in great measure due to the cumulative effect of the rays absorbed in the course of a specialist's practice. In radioscopy a plate of rock crystal should be interposed between the fluorescent screen and the observer. This will arrest the X-rays without modifying the light.

In addition, the practitioner should wear spectacles, with large thick lenses of flint or lead glass. Much better is the habitual use of the localizer already described, which entirely prevents any injury to the eyes of the operator.

Personally, we have never seen the slightest injury to internal organs or to the nervous system follow the therapeutic application of X-rays, and this in spite of the fact that we have frequently used exposures of considerable intensity. *Scholtz* and other foreign authors have had the same experience, and found that even when ulceration of the surface of the abdomen occurred in consequence of severe irradiation, it was not followed by any intestinal lesion.

We have frequently irradiated the eyelids, and have never seen the slightest injurious effect on the eye itself. At the present time

we have under treatment a case of epithelioma of the eyelid and tissues surrounding the eyeball. This case has improved considerably under doses of 7 H. or 8 H. repeated once a month. Subsequent careful examination by an oculist revealed no injury to the eyesight.

It may be objected that the rays employed in radiotherapeutic treatment are of feeble penetrating power, and, being arrested by cutaneous surface, have but little action on the subjacent tissue. Putting on one side the possibility of a selective action, we may suppose that any rays which reach an internal organ will be of sufficient penetration to pass through it without marked effect, and that the softer rays, which would be more readily absorbed, will have been already in great measure arrested by the superficial tissues.

At all events, in practical radiotherapy we may rest assured that, under the conditions obtaining in practice, no injurious action on internal organs is to be feared.

X-rays act more especially on the skin and its appendages. It is there that reaction occurs, and modifications of tissue in direct proportion to the amount of radiation absorbed.

2. *Objective Symptoms of the Skin due to X-Rays.*

We have already alluded to the baneful results of X-rays on the skin. A volume might be written on the accidents which have been attributed to their action since their discovery by *Roentgen*. It is of interest to notice that most of the more serious accidents occurred in the earlier years, when radiography and radiotherapy were in their infancy.

Nowadays one seldom meets with those cases of extensive ulcerative dermatitis which used to last for months and sometimes for years. One usually sees nothing more than some superficial modification of the cutaneous tissue or a slight erosion purposely provoked by the operator in the treatment of the disease. In many cases of X-ray dermatitis we purposely set up what the older writers called a slight accidental reaction, but what may be more appropriately termed a curative dermatitis. When the skin is exceptionally irritable, or the quantity of rays absorbed considerable, the reaction will be more marked, and we may get superficial

ulceration, followed by scarring. This degree of reaction is often purposely produced in the treatment of malignant tumours.

Exposure to the Roentgen rays is quite painless, the patient feeling absolutely nothing. He may possibly be conscious of a slight degree of warmth due to the heat of the tube, or more probably to the warmth of the protecting shield. We have never been able to observe the gastric irritations, the headaches, palpitations, cardialgias, etc., described by *Oudin* in *Bouchard's* 'Traité de Radiologie,' and confirmed by such writers as *Walsh*, *Seguy*, and *Quenisset*. We do not, however, follow exactly the same procedure as these authors.

It is true that at the termination of a séance some patients complain of a little giddiness and heaviness of the head, but this is probably due to the constrained position they occupy during an exposure. They are placed lying down on a couch, with the head low, in a warm room; and to some patients the noise of the mechanical break is most fatiguing. All this is quite sufficient to explain the occurrence of some temporary malaise.

Oudin and *Kienböck* more especially have studied the objective symptoms of the irradiated tissues. We shall quote largely from their works in the following pages.

Stage of Latency.—We must first determine the point at which reaction commences. Is there any stage of latency between the irradiation and the first signs of a consequent dermatitis?

According to *Oudin's* observations, from twenty-four to thirty-six hours after exposure a slight progressive erythema indicates the commencement of reaction. *Scholtz* and *Kienböck* give a longer period of latency.

'Usually,' says *Kienböck*, 'irradiation is followed by a long period of complete latency. Erythema or epilation occurs only after a period of ten or twelve days' latency, even when a very considerable dose of the rays has been given.'

To determine the interval between an irradiation and the commencement of reaction, *Scholtz* made a series of experiments on young pigs.

He says: 'The time that elapses before the appearance of any visible reaction is rather longer after a moderate irradiation than after one of greater intensity. After a very intense exposure there is a latent interval of seven or eight days, and the reaction does not attain its maximum till after a further period of some weeks.'

Occasionally after a radiotherapeutic sitting an erythema will appear on the same evening or on the next morning. This fact is vouched for by several authors, and we have ourselves often witnessed it. Some authorities consider this as the commencement of a true reaction, but *Scholtz* and *Kienböck's* observations are directly opposed to this view. To what, then, is the phenomenon due?

The following is the usual course of events: An evanescent erythema appears the same evening or the next morning after irradiation. It acquires its maximum in a few hours, and then decreases gradually, disappearing entirely in four or five days. It is usually accompanied by slight itching. The redness which ushers in the true X-ray reaction begins to appear as this evanescent erythema is dying away. By this time the minimum period of five or six days' latency following a severe exposure has elapsed. This gives rise to the erroneous idea that the commencement of X-ray reaction coincides with the end of the primary erythema. It is often said, 'Roentgen reaction commences immediately after the exposure and increases progressively.' If patients are carefully questioned, however, two distinct phenomena may be recognised. Moreover, in many cases, the primary erythema does not occur, and it is only after the lapse of some days that the true reaction shows itself. We may therefore assume that the occurrence of local evanescent redness has no connection with the true Roentgen ray reaction. *Kienböck*, in Vienna, and *Béclère*, in France, are also of this opinion.

The occurrence of this evanescent consecutive erythema may be completely avoided by the use of water-cooled tubes, which prevent the anticathode from becoming too hot. Many experimenters vouch for this fact.

Some observers attribute the occurrence of early erythema to the action of unknown rays emanating from the violet-coloured layer which forms in focus-tubes after long usage. *Schmidt* opposes this idea. 'Primary erythema,' he writes, 'is quite independent of the age of the focus-tube, and happens just as often with new as with old tubes. In some individuals the primary erythema occurs on every occasion when a sufficient dose of X-rays has been absorbed. It is probably the result of a special irritability of the vascular system, such as may be frequently observed with other influences of psychic, thermic, or toxic origin.'

This pseudo-reaction is in all probability due to the action of the luminous rays emitted by the anticathode when in a state of incandescence. A similar erythema is seen in sunburns, or as the consequence of exposure to electric light. Perhaps a certain amount of heat may add to the light effect.

The true reaction, then, does not occur till after the lapse of several days. The period of latency varies with the quantity of X-rays absorbed by the skin, the idiosyncrasy of the patient, and the region of the skin which has been irradiated.

If the exposure has been a moderate one, the erythema or alopecia may occur after an interval of eight, ten, or twelve days, whereas if the application has been more intense, the latent period will be only five or six days.

Kienböck thus sums up the matter: 'The stronger the dose given during a séance, the shorter the period of latency, the sharper the reaction, and the longer its duration.'

Radiodermatitis.

There are two varieties of radiodermatitis—acute and chronic. This is the nomenclature adopted by *Kienböck* and *Oudin*. 'These terms are inaccurate,' says *Oudin*, 'if they are applied to the course and duration of the affection. The terms "acute" and "chronic" refer to the causes of the dermatitis, and not to its evolution.'

Although this classification is useful in practice, it may mislead a beginner in radiotherapy. There are not two varieties of dermatitis; what varies is the intensity of the phenomenon, and the special forms which it assumes in different regions of the body. The radiodermatitis following a severe exposure is not comparable with that which follows a more moderate irradiation. The operator who makes daily radioscopic examinations is subject to lesions of the hands which do not in the least resemble the ulceration which follows an intense exposure. In the course of a few minutes a patient will receive a quantity of X-rays equal to that which is absorbed by the operator during a period of many weeks, in small and frequently repeated doses. The course of the reaction will naturally differ in the two cases; in the latter instance certain phases may be suppressed, or the progress of the dermatitis may be arrested at an early stage. Nevertheless, in their origin the two cases are identical, the differences being solely due to varia-

tions in the sensitiveness of the patient and the intensity of the irradiation.

For purposes of study, however, we may distinguish two distinct varieties of dermatitis—that of the patient and that of the operator.

RADIODERMATITIS OF THE PATIENT.

There are many degrees of radiodermatitis affecting the patient. The different forms are not absolutely distinguishable, and may vary in many ways. The reaction may skip one or more stages, and be arrested at any one of them; or it may pass on successively through the usual forms, ending in ulceration and scarring. The following description gives a general view of these reactions, which are not always evolved in the same order.

Alopecia.—Shedding of the hair is an early result of X-ray irradiation, and occasionally occurs without any other evidence of reaction. This alopecia, without marked erythema, is especially noticeable on the scalp. After an exposure of moderate intensity, the hairs begin to fall in twelve to fourteen days; this continues until little by little complete alopecia is produced.

According to some observers, a slight erythema always precedes the shedding of the hair. There is great divergence of opinion on this subject, which may be due to the difficulty of observing an erythema of the hairy scalp.

For some little time after the loss of hair, the skin remains smooth and bare, without any other alteration than an occasional slight pigmentation. After some weeks the skin returns to its normal aspect, and the hairs begin to grow again. Three or four months after the irradiation the reaction will have completely died away, leaving no trace behind.

Similar phenomena follow the irradiation of the face. Here, however, it is more usual to get a more or less acute erythema, followed in some cases by pigmentation and atrophy of the cutaneous tissue. If an excessive quantity of X-rays has been absorbed, the erythema will be more intense, and some infiltration and even vesiculation may precede the occurrence of epilation. The form as well as the degree of reaction depends in great measure on the intensity of the irradiation.

According to *Kienböck's* observations, the reaction is frequently arrested before a complete alopecia has taken place.

Erythema.—An erythema is usually the first result of an irradiation of somewhat greater intensity. It shows itself five or six days after the exposure, the skin becoming rosy red over the whole of the area which has been irradiated.

Occasionally, instead of being uniform, the erythema may be punctate or lenticular at first, the spots speedily uniting, and the whole area becoming deeper in colour. The extent of the erythema is often accurately outlined by the edge of the protecting shield. At this stage any hairs which may be present are still adherent. Sensation is in no way modified, with the exception that itching may occasionally occur.

In the course of two or three days the rosy tint is succeeded by a deeper coloration. The skin becomes successively bright red, deep red, brownish red, and sometimes violet, reminding one of the varying colours which chilblains assume. In some cases the erythema is continuous in the centre of the irradiated area, while disseminated spots occur near the margin.

At the same time the skin becomes slightly infiltrated, showing a slight amount of œdema. The itching, which has hitherto been slight, becomes more severe, especially at night, when it is aggravated by scratching. The erythema attains its maximum two or three weeks after the date of irradiation, and the reaction is usually arrested at this stage. If, however, the duration of exposure has been excessive, the reaction becomes still more severe, and the erythema may be followed by more serious symptoms.

In a favourable case, the hyperæmia diminishes and the itching is calmed in the course of a few days. At this stage the hairs begin to fall out, and complete alopecia usually follows. In some cases however, a sharp inflammatory reaction may produce only a partial epilation. The fading of the erythema is frequently followed by desquamation, during which the superficial layers of the epidermis are shed in minute furfuraceous scales, leaving the subjacent skin in a perfectly normal state.

Pigmentation.—In *Kienböck's* opinion, erythema is always followed by a brown-coloured pigmentation, which continues until it is ultimately removed by the occurrence of desquamation. We have however, frequently witnessed the disappearance of erythema without any trace of desquamation. This abnormal discoloration of the skin following irradiation, varies very much in different individuals, and, according to *Oudin's* observations,

it frequently extends to a considerable distance from the affected region.

In a case of severe X-ray burn with ulceration of the abdomen, the pigmentation extended over the whole of the anterior surface of the trunk and thighs. The pigmentation which follows hyperæmia is, however, more usually limited to the irradiated area. The discoloration is much more marked in patients whose skin is naturally pigmented, brunettes reacting in this respect much more readily than blondes.

The hyperpigmented skin after a few days begins to desquamate with the production of minute brown scales of varying size. According to *Kienböck*, the skin after desquamation is left white, shining, bare of down and hair, and exceedingly thin in texture. Ultimately it regains its normal aspect. The time required for the evolution of all the stages of reaction is very varied; the minimum may be fixed at six weeks, but it is impossible to indicate a maximum.

In exceptional cases, to the despair of the patient, pigmentation remains behind after all other signs of reaction have disappeared. This may not be very serious, but in some cases the patient is disfigured by stripes of deep pigmentation, like a tiger skin. Under these circumstances one must inculcate patience; the brown discoloration will usually disappear after the lapse of some months. It is prudent to warn dark-complexioned patients of the possibility of this accident, more especially if the treatment necessitates the production of an intense reaction.

Ehrmann of Vienna considers that a difference of causation underlies this variation in the duration of pigmentation, distinguishing two distinct pathogenetic processes resulting in pigmentation The one, more evanescent, is due to the production of hæmosiderin, and its introduction into the cutaneous vessels. It is deposited in the intercellular spaces, and produces a brownish tint, which after a time may be completely absorbed. On the other hand, the more serious variety of pigmentation is caused by the direct action of the Roentgen rays on the melanoblasts of the skin, and may subsist for years.

Vesiculation; Phlyctenulæ.—The erythema resulting from an intense irradiation may be followed by more serious symptoms. Instead of fading away and disappearing, it becomes more pronounced.

On the red erythematous surface elevations begin to appear, which are of different sizes, and may be acuminate or papular. In the early stage they are barely visible, and resemble ordinary congestion papules. If however, their surface is scratched with a needle, a yellow, serous, slightly opaque fluid exudes, and the papule disappears. These elevations, though of small size, are in reality vesicles. They occur in groups or disseminated over the surface, and ultimately develop into vesico-bullæ, or vesico-pustules, which have the appearance of an ordinary eruption. At this stage the inflammatory process may be arrested, and the skin may return to its normal state after the lapse of some time. In certain cases pustules appear at the margin of the surface which has been irradiated. *Sabouraud* observed this occurrence in a number of cases of tinea which he was treating by epilation, typical pustules appearing around the epilated region, just at the margin of the healthy hair. These disappeared after a few days' treatment with sulphur lotions.

It is difficult to determine their exact nature, as they did not resemble trichophytic lesions, and did not appear on the central part of the irradiated surface. They did not seem to be the result of excessive exposure, but were probably due to the action of secondary X-rays.

Superficial Ulceration.—The vesicles above described do not always remain disseminated, but may become confluent. This usually happens when the period of latency has been a brief one of about ten days' duration. Under these circumstances, bullæ and phlyctenulæ appear, which may only attain the size of a lentil, or may grow much larger. The contents are at first serous, then opaque, and finally purulent.

Later on they burst, leaving an ulcerated discharging surface. The skin between the phlyctenulæ may become softened and break down, with detachment of the epidermis, leaving the whole surface bare of epithelium, and of a deep red, purple, or violet colour.

When the phlyctenulæ rupture, the itching, which has hitherto been severe, gives place to more painful sensations. Smarting and burning of an insupportable character render rest or sleep impossible. 'The patient,' says *Oudin*, 'cannot even bear the contact of the sheets.' This condition may last from ten to thirty days before the process of healing commences. When the new skin is

formed, it is thin, smooth, white, and atrophic, with cicatrices here and there. The hair follicles are atrophied, and consequently the alopecia is permanent. Occasionally deep pigmentation of the surrounding skin remains, with numerous telangiectases, which leave indelible scars. *Ehrmann*, *Teleky*, *Spiegler*, *Balzer*, and others, report numerous cases of similar gravity.

The Roentgen Ulcer.—We must now turn our attention to the most serious sequel of radiodermatitis, the Roentgen ulcer. It is seldom seen at the present day, but was not uncommon in the early days of radioscopy. It is the result of the most severe degree of dermatitis, and consists of more or less extensive necrosis of the skin. There is, however, no distinctive type of Roentgen ulcer; there are many different forms of varying severity, depending on the irritability of the skin and the quantity of rays absorbed. In some cases the ulceration is quite superficial, the epidermis only being destroyed, with but little invasion of the true skin. In other cases the lesion goes much deeper, extending to the whole thickness of the dermis, and even attacking the subjacent tissues. This constitutes the gravest form of the Roentgen ulcer, in which the pain is much more severe, sometimes becoming terrible in its intensity, and often radiating to adjacent parts. In the preceding stage the ulcerating surface was of a uniform red colour throughout. Now spots appear on its surface, yellow, gray, or blackish in aspect, which spread, run together, and form a slough, which does not extend beyond the irradiated surface. Little by little the slough becomes drier in consistence, blacker in colour, and less sensitive, until finally it lies mummified and retracted in the centre of the living tissues which surround it. Between it and the healthy tissue a groove appears, from which oozes a thick liquid of serous or purulent character, and finally the slough becomes detached from the subjacent tissues, and a deep ulcer remains, bathed in abundant secretion. In favourable cases, after some weeks granulations appear and the process of repair commences, and may result in complete healing. Frequently however, the ulceration is of a more torpid character, showing no signs of cicatrization, and it may even increase in extent and depth. This process, as *Kienböck* has shown, may continue for months or even for years, and is in certain cases characterized by a complete absence of pain.

There is another type of primitive Roentgen ulcer following

excessive irradiation, which, after a latent period of five to eight days, commences by necrosis and ulceration.

Happily, such accidents are rare—in our experience we have not met with a single case. They are the result of unskilful treatment, requiring an irradiation of from ten to twenty times the maximum normal dose.

Mademoiselle H. de Pissareff, in her inaugural thesis on radiodermatitis, writes: 'The healing is desperately slow; the resulting cicatrix, with its margins indented like a geographical map, and the hyperpigmented skin around it, is absolutely characteristic. Like the scar of any other serious burn, it continues to contract for many months after its formation, thus adding greatly to the deformity.'

Gocht also remarks that the hyperpigmentation and telangiectases following X-ray burns are most persistent in character.

According to some foreign observers, neoplasms of a malignant nature have arisen in the scars following severe radiodermatitis. *Kümmel* of Hamburg has just published the case of a medical practitioner in whom cancer developed in the scar following X-ray dermatitis. *Allen* has lately communicated a similar case to the American Society of Dermatology.

It is doubtful if the X-rays directly determine the growth of the neoplasm. It is more reasonable to suppose that the cicatrix, being a point of least resistance, may be more vulnerable to a new disease. As is well known, cancer attacks skin which has been affected by chronic inflammation and sclerosis. We do not believe that the X-rays produce cancer, since this malady may be grafted, as it were, on lesions and cicatrices of the most varied origin.

The lesions of radiodermatitis are not in any way typical in appearance. The various distinctions are useful only as facilitating description. The irradiated skin reacts more or less intensely in accordance with the idiosyncrasy of the patient and the amount of the X-rays absorbed. The reaction may pass through all the above-mentioned stages one after another, it may be arrested at any stage, or it may miss one or more stages.

Carl Beck defines three degrees of radiodermatitis:

'The first degree is characterized by hyperæmia and infiltration of the skin, accompanied by exfoliation of minute scales and a considerable amount of itching. Atrophy of the appendages of the skin, glands, hair, and nails may follow.

'The second degree of dermatitis is characterized by the occurrence of vesiculation and phlyctenulæ. Inflammatory signs are severe, the tension considerable, and the pain intense. Under the phlyctenulæ the bared chorion appears, red and discharging.

'The third degree is characterized by total destruction and sloughing of the irradiated tissues. These show the usual signs of dry gangrene; the sloughs separate slowly, leaving behind an ulcer of a very torpid nature, which sometimes remains unhealed for years.'

The Later Accidental Lesions.—Signs of radiodermatitis usually appear in the course of the first fortnight after exposure. Sometimes however they are delayed, making their first appearance after a very prolonged interval. *Oudin* and *Barthélemy* reported a case of ulceration in a female patient occurring five months after the cessation of all radiotherapeutic treatment. The patient had been exposed to an irradiation of the mammary region to relieve neuralgic pain. The ulceration lasted more than a year, and was extremely slow in healing.

Oudin relates a case which occurred in *Professor Fournier's* clinique, of a woman in which trophic disturbances set in ten months after a course of radiotherapeutic treatment, although during the interval the skin had remained perfectly healthy in appearance, without any sign of redness, eruption, or pain. In the course of another two months the case passed through all the stages of dermatitis, ending in ulceration and sloughing.

In 1900 *Oudin* published two similar cases. In a patient treated by *Dr. Bar* by irradiation, a serum injection was rapidly followed by sloughing at the seat of puncture. This was followed by mortification, without suppuration, of the whole of the tissue infiltrated by the serum. In another case, six months after a course of radiotherapy a hot douche on the apparently healthy surface set up ulceration similar to that caused by radiodermatitis.

According to this author, moreover, a slight traumatism in the neighbourhood of a dermatitis, or an injury to an apparently healthy surface which has been irradiated, may set up a characteristic ulceration. The greatest caution should therefore be exercised in carrying out any operative procedure after a long exposure to X-rays.

An observation of *Kienböck's* illustrates this point. In experimenting on a rabbit which had recovered from a dermatitis of the

second degree, a relapse occurred in consequence of a slight accidental injury to the affected region.

Happily these more serious accidents occurring after a considerable lapse of time are extremely rare, and may be regarded as scientific curiosities. They all date, moreover, from the early days when radiotherapy was in its infancy, when the technique was defective and empirical, and the nature of the active agent unknown. Occasionally, too, results were attributed to the rays for which they were not responsible. In the course of a radiotherapeutic practice of more than two years, we have never met with a case of this nature.

Fortunately, we have passed the epoch alluded to by *Oudin:* 'When we see an erythema appear after an X-ray séance, it is impossible to predict what will happen.' With the modern facilities for regulating the dose, we are now able to avoid accidental dermatitis with some degree of certainty. With even greater certainty may the so-called 'late reactions' be avoided.

The varying degrees of radiodermatitis may be best differentiated by classing them, as *Kienböck* does, according to their different periods of latency.

First Degree.—Latent period of about three weeks. No visible inflammation of the skin: temporary shedding of hair; diminution of lupus nodules; exacerbation of pre-existent congestive phenomena.

Second Degree.—Latent period of two weeks. Tumefaction and erythema lasting one or two weeks; shedding of hairs.

Third Degree.—Latency of ten days. Redness, vesication, erosion, and exudation; *restitutio ad integrum* in from three to four weeks.

Fourth Degree.—Latency of from five to eight days. Necrosis followed by ulceration; cicatrization after six weeks or more.

A year or eighteen months after a radiodermatitis of the second degree, there sometimes occurs a singular atrophy of the skin, accompanied by telangiectases. This atrophic condition occurs almost invariably after a radiodermatitis of the third degree.

RADIODERMATITIS OF THE OPERATOR.

The radiodermatitis which affects the operator is usually of a chronic character. It is often called a chronic radiodermatitis, although the term is not a good one. The chronic and the acute

varieties of dermatitis have precisely the same etiological factors; there is only a difference in intensity.

Its outward appearance is very different from that of an acute dermatitis. It is slow, progressive, and insidious in its commencement. It occurs in those who are habitually exposed to the action of X-rays, and usually attacks the hands, which are chiefly exposed to the rays in the practice of radiography and radioscopy, and are often brought into proximity with the tube in radiotherapy.

This variety of radiodermatitis has a long period of latency, since the irradiations which produce it are of short duration and feeble intensity. Its occurrence is due to the continual addition of small doses producing a cumulative effect, which may continue for many weeks or months.

Kienböck and *Oudin* have specially studied these lesions. They are not however in complete agreement as to the initiatory signs. The latter considers that in the early stages it is the capillary circulation which is chiefly affected. The first symptom observed may be a certain amount of acrocyanosis, the fingers becoming red or violet in colour and coarse in texture, with a feeling of heat and dryness of the skin, unaccompanied by pain. Subsequently a diffuse erythema appears. This is most marked on the second and third phalanges, which often become swollen, as if from chilblains.

Kienböck describes the first degree of chronic dermatitis as consisting of an atrophy of the hair papillæ, with complete alopecia, the hairs returning once or twice after being shed, and then finally ceasing to grow. This is the ideal result to be aimed at in the treatment of hypertrichosis. There may be more or less atrophy of the skin and cutaneous glands, but, according to *Kienböck*, the most important symptom is the shedding of the hair. *Oudin* disagrees with this view, and reports in detail the course of the reaction in his own case. The skin of his hands became erythematous and infiltrated; all the suppleness of the skin was lost, but the hairs were not shed. Both *Kienböck* and *Oudin* are probably correct, the difference in the two cases depending on the irritability of the skin and the quantity of rays absorbed. The distance of the focus-tube, the duration of exposure, the difference in the penetration of rays used in radioscopy and radiotherapy respectively, and finally, the stimulative effect of the rays, must all be taken into account as factors modifying the aspect and progress of the reaction. In some cases the skin of the hand becomes gradually thinner, is thrown into

wrinkles, and becomes atrophic. In other cases the dermis thickens, and becomes less supple; the normal folds are accentuated, and the pigmentation increases. These modifications, says *Kienböck*, may often be seen on the dorsum of the hands of those who employ X-rays professionally. The back of the hand is coloured of a reddish brown, and the down on the skin is diminished in quantity and atrophic in character.

This condition of cutaneous acromegaly may become very painful. There is thickening of the finger-tips, and cracks appear on the borders of the nails, which reopen continually and are apt to bleed.

The skin is wrinkled, desquamates in places, and may become the seat of active exfoliation of the epidermis, accompanied by extensive telangiectases. The palmar surface may be affected in a lesser degree.

Dr. Brocq has kindly communicated notes of two cases of epithelioma occurring in the hands of surgeons practising radiology.

The inflammation caused by X-rays in small and frequently repeated doses resembled that of xeroderma pigmentosum, consisting of erythema, spots of pigmentation, desquamation, exfoliation, angioma, warty growths, and, finally, epithelioma. This is an interesting observation, but we have not hitherto met with a case presenting all these appearances in the same subject.

The nails are frequently affected. They acquire a brown colour, are flattened, channelled, and split. As *Hahn* points out, they may take on the appearance of claws. The groove of the nail becomes cornified, and filled up under the edges and behind with masses of detached epidermis. The nail itself becomes brittle, and often falls off entirely or in part, leaving the subjacent epidermis thickened and scaly.

As *Oudin* says, ‘The troubles of nutrition in radiodermatitis are not confined to the skin. All observers are agreed that if the exposure has been sufficiently prolonged, a notable thickening of the periosteum occurs, especially in the phalanges. A radioscopic examination of the hands shows that the bones are not affected. Moreover, the articulations are increased in size, and in my own case I noticed that the periarticular tissues were also hypertrophied. This greatly aggravates the discomfort and difficulty of flexion. A certain amount of tremor in the fingers was also noticed. *Hallopeau* and *Gadaud* have also described lesions of this characte occurring in the hands of professional radiographers.

In most cases the above degree of reaction goes no further; for the operator, warned by its occurrence, ceases to expose his hands to the rays, and the dermatitis slowly disappears. If, however, the warning is neglected, the dermatitis increases, and a condition supervenes resembling an acute eczema. *Kienböck* reports a case of long-continued torpid ulceration of the hand, with destruction of the tendons and ligaments of the articulations.

In order to understand the causation of these serious accidents, we should bear in mind that the irradiation of a tissue greatly reduces its power of resistance to injury. This fact has been particularly emphasized by *Kienböck* and *Elihu Thompson.*

The foregoing pathological conditions are the usual results of a long series of exposures of the operator's hands in the course of radiography or radiotherapy. Occasionally, however, the early signs of reaction do not increase, but remain stationary. We have lately had under our observation a medical practitioner with a large practice in radioscopy and radiotherapy. The skin of his hands has for a considerable period been dry, cracked, wrinkled, and squamous, without showing the slightest tendency to progress to a more severe form of dermatitis. The hands are however, slightly more irritable in the winter months.

Treatment of Radiodermatitis and Means of Protection.

A benignant radiodermatitis with slight erythema disappears spontaneously in a few days. If the irritation is excessive one may apply compresses of boric acid, a soothing ointment of oxide of zinc, or goulard water, as recommended by *Kümmel*, *Schiff*, and *Albers-Schoenberg*. In order to reduce the pigmentation, electrolysis and high-frequency currents have been tried, but without much effect. *Toröck* and *Schein* prescribe a naphthol pomade. *Ali Krogius* recommends liquid thiol as very efficacious in the treatment of radiotherapeutic erythema. Moreover, thiol may be used as a prophylactic, being impermeable to X-rays. In the treatment of tumours by radiotherapy the adjacent skin may be covered with a thiol plaster during irradiation.

The only efficient treatment of chronic dermatitis is the complete suppression of the cause. The hands must not be brought near a focus-tube. No topical application, no dressing will give the

slightest amelioration as long as the hands are continually exposed to the rays. Instead of submitting to a complete abstention from radiotherapeutic work, the practitioners may protect the hands by one of the following devices :

We need only allude *en passant* to the precautions taken by those radiographers who cover themselves with veritable suits of armour, including casque and gauntlets of lead.

The most important point is to protect the hands. *Oudin* originally wore gloves covered with a sheet of lead, but these were very awkward in use. He now prefers fencing-gloves, which are covered by a thin sheet of brass, and finds that these give a sufficient protection.

Béclère formerly used gloves having copper shields which covered the back of each finger, leaving the palmar surface bare. This is sufficient for radioscopy, but of no use in the practice of radiotherapy. More recently he has adopted the use of ordinary gloves with little bags sewn on the back of the fingers. These are filled with bismuth powder, which readily adapts itself to the form of the fingers, and does not interfere with the movements of the hand.

Since it has been scientifically demonstrated that the X-rays have an injurious action on the testicles, producing necrospermia, followed by azoöspermia, it may be a question whether these organs should not have some protection. If this is thought necessary, it may be attained by an apron consisting of a double layer of caoutchouc filled with bismuth powder. In our opinion this should be worn by all practitioners of radiotherapy.

The simplest means, however, of protecting one's self from the action of X-rays is to keep as far as possible behind the cathode.

Some time ago we designed a lead-covered wooden box to contain the focus-tube. More recently, at our request, Gaiffe has constructed a special localizer, which has already been described. This is the most efficient protection possible against the occurrence of dermatitis, and with its use the necessity of wearing spectacles and other awkward encumbrances entirely disappears.

Every variety of treatment has been tried for the graver forms of radiodermatitis, and all of them have failed. Iodoform and picric acid, which would seem to be especially indicated, have proved quite useless. Antiseptics are of no avail, and only aggravate the condition. The lesions show but little tendency to

become the seat of secondary septic infections. 'Their surface,' says *Oudin*, 'does not inflame, and hardly ever suppurates; it has no odour, and, what is still more strange, does not give rise to lymphangitis or affections of the glands. For instance, one may often see lesions of considerable extent in the neighbourhood of the axilla, without any enlargement of the glands, and this even when the case has not been treated antiseptically.

Protective dressings are however required where there has been destruction of the epidermis, laying bare the subjacent structures. The contact of the air with the ulcerated surface aggravates the condition and increases the pain. It should therefore be covered with a thick layer of cotton-wool, and cocaine may be used to allay the pain, if intense.

In a case of superficial ulceration we obtained rapid cicatrization by covering the part with a thick layer of zinc ointment, which was in its turn protected by a sterilized dressing.

With the same end in view, we may employ the linimentum calcis, which is excellent in cases where the sensation of burning is severe; or we may employ the following pomade, recommended by *Walker*:

Prepared chalk	15 grammes
Olive-oil	8 ,,
Prepared lard	4 ,,

Another formula given by *Engmann* is:

Acid. boric.	45 grammes
Ol. olivæ	30 ,,
Lanoline	90 ,,
Aq. rosæ	45 ,,

Usually the linimentum calcis is the most grateful for the relief of pain. It is applied freely to the surface, which is also covered by lint soaked in the liniment.

Dr. Bar conceived the ingenious idea of treating a case of severe radiographic ulceration by means of red light. Under its use the reparation of the lesion was much more rapid than might have been expected normally.

The ulceration was situated on the abdominal wall. A wooden case was constructed enclosing the entire abdomen. The cover of

this box consisted of a plate of red glass. Shielded by this apparatus, the patient was exposed to the light of the sun for some hours each day, the cover being so adjusted as to be 5 centimetres from the ulcerated surface.

'Theoretically,' says *Oudin*, 'this experiment is of the greatest interest, when we remember that the red and infra-red rays are antagonistic in their action to the violet and ultra-violet rays. On a photographic plate the ultra-violet rays and the red rays have a diametrically opposite action. A fluorescent screen is excited by the ultra-violet rays, whereas the fluorescence is destroyed by the red rays of the spectrum. Moreover, we know that the superficial lesions produced by X-rays are precisely similar to those set up by the chemical rays of the spectrum. It is therefore reasonable to suppose that there may be a physiological, as well as a chemical, antagonism between the red and the violet rays. This view appears to be supported by *Bar's* experiments.

We have had an opportunity of trying this mode of treatment in a patient suffering from a benignant form of radiodermatitis. The case was one of mycosis fungoides, and had been subjected to an exposure of somewhat excessive duration. An ulceration of the frontal region the size of a five-shilling piece resulted. The epidermis alone was shed. The ulcerated region was regularly exposed each day to the rays of a red lamp. Rapid cicatrization followed in this case.

On the other hand, whereas an obstinate ulceration of the elbow resulting from injury was rendered worse rather than better by exposure to red light, blue light has been recommended by *Kaïser* in the treatment of radiodermatitis. In 1901, at the Hamburg Congress, he reported very satisfactory results following this treatment.

Strebell has not met with favourable results from the use of blue light, but *Montgomery* considers blue light to be a direct stimulant of cell growth.

In reality most of the published observations prove nothing as to the effect of light. *Bar's* experiment is inconclusive. One half of the ulcer should have been covered by a red glass, while the remaining half remained under a white glass. If under these circumstances one side had healed more rapidly than the other, we might legitimately conclude that the healing action was due to the incidence of the red rays. In many of the cases reported

we may attribute the improvement to the effect of light itself, regardless of any special coloration.

Freund believes that cold has a most disastrous influence on radiodermatitis, whereas warmth is beneficial. He prescribes fumigations and cataplasms. In conjunction with *Professor Ehrmann*, he treated two severe cases of X-ray ulceration by exposure to an incandescent electric light of a hundred-candle power, which was applied daily for half an hour at a time. The pain was greatly relieved and cicatrization speedily followed. In this case the result was probably due to the action of light.

Electricity in various forms has been tried, without much success. A case treated by *Apostoli* was benefited by the effleuve from a static machine, the pain diminishing and the wound healing rapidly. *Oudin* successfully treated a case of radiographic ulceration of the ankle by means of the effleuves from a resonator. In this case the condition improved and healing set in rapidly, cicatrization being complete in the course of a month, whereas there had been no alteration of the ulceration during the preceding four months. The applications of the high-frequency current were of about ten minutes' duration, and were repeated three times a week.

Electric baths appear in some cases to have given good results. We reproduce *Dr. Schwartz's* observations on this subject. In July, 1898, the patient made a series of experiments with Roentgen rays. Soon afterwards an exceedingly painful erythema appeared on the back of the right hand. This was followed by shedding of the epidermis, and extensive ulceration spreading over the whole dorsal surface of the hand and laying bare the deeper tissues. An atonic ulcer remained, with precipitous edges, on a bleeding fungous base, with no signs of reparation.

The patient complained of severe pain, with burning and smarting that no treatment seemed to allay. Salol plaster, boric acid powder, baths, orthoform, and other applications were all in vain. The hand was then treated with electric baths, a continuous current of feeble intensity being used. Cicatrization at once set in, and the wound soon healed completely after a total duration of eight months. Sinusoidal and triphasic currents may also be used in the treatment of radiodermatitis by means of electric baths.

Some observations of *Huntington's* seem to show that the Roentgen ulcer is due to a vaso-motor disturbance, resulting in contraction of the arterioles and consequent death of the tissue.

He advises a radical cure by surgical means. His case was that of a patient aged thirty-five years, who had an ulcer of six months' duration on the abdomen, following ninety-nine radioscopic exposures. On the right side of the abdomen, below the level of the umbilicus, was a patch of dermatitis as large as a saucer. In the centre of this was an ulcer about 1 inch across, the borders of which were acutely hyperæsthesic. Around this, again, was a hyperæmic zone, which was the seat of violent itching.

Huntington extirpated the ulcerated area by a deep incision down to the sheath of the rectus muscle. The panniculus adiposus was found much sclerosed, and was dissected out for some distance beyond the incision. The margin of the skin was sutured to the muscular sheath, and the loss of tissue was made good by the use of skin-grafting after Thiersch's method.

The result was quite satisfactory, and the wound has remained sound ever since, the cicatrix being slightly red, but with no tendency to ulceration. An annular keloid elevation surrounds the site of the wound.

This result is of interest, and is in opposition to the generally received opinion that all surgical interference, even scraping, should be avoided, and that skin-grafting rarely succeeds in these cases.

3 *Action of X-Rays on Bacteria.*

The microbicidal action of X-rays has been the subject of much discussion. Do they stimulate the development of bacteria and render them more virulent, or do they destroy them?

On the one side we have a number of observers who maintain that X-rays have no action on the life or development of bacteria. Among these are *Wolfenden* and *Forbes Ross*, *Beck* and *Schültz*, *Beauregard* and *Guichard*, *Bergonié*, *Destot* and *Dubar*, *Berton*, *Brunton*, *Blaikie*, *Blaise*, and *Sambuc*, *Grunmach*, *Mink*, *Pott*, *Sabrazès*, and *Rivière*, *Sarmani*, *Kümmel*, *Wittlin*, *Wolff*, and many others. On the other side we have *Bonomo* and *Gros*, *Fiorentini* and *Luraschi*, *Frantzius*, *Lortet* and *Genoud*, *Muhsam*, *Rieder*, *Halzknecht*, *Spieler*, and others, who have been successful in diminishing the virulence of microbic cultures, in arresting their development, and even in determining their destruction by irradiation with Roentgen rays.

One of the principal partisans of the bactericidal effect of the

rays is *H. Rieder.* His experiments were made on plate cultures in agar-agar of the vibrio of cholera, Eberth's bacillus, the bacillus of diphtheria, and others, previous to exposure to the X-rays. The plate was covered by a leaden shield having a central aperture.

The time of exposure varied from one to three hours, the distance from the anticathode to the plate being 4 inches. A 12-inch coil was used, with 800 interruptions per minute.

Koch's bacillus and the vibrio of cholera both showed an arrest of development over the irradiated area after an exposure of forty-eight minutes. The part of the culture screened by the lead shield was totally unaffected. When the plate was placed in the incubator, the bacteria developed over the whole of the protected portion of the plate, but did not do so over the irradiated area.

An exposure of from one to three hours destroyed the cultures entirely.

Similar results were obtained when a metallic plate was interposed between the focus-tube and the culture in order to cut off all electric discharges. Positive results were obtained also with the *Bacillus coli*, *Staphylococcus pyogenes*, and the bacillus of diphtheria.

From his experiments *Rieder* comes to the conclusion that the Roentgen rays have a distinct bactericidal action. He says, 'We do not require to destroy the bacteria in the interior of the human body; we need only offer an obstacle to their development. The blood, which is the natural guardian of the organism, will suffice to complete the destruction of pathogenic germs, since it also possesses well-defined bactericidal powers.'

Aschkinass and *Caspari* were successful in producing an arrest of bacterial development by means of X-rays. For their experiments they chose the *Micrococcus prodigiosus*, on account of its strong odour and the red colour of its cultures.

Danysz confirms their observations. All the microbes on which he experimented were arrested in their development, and in some cases, notably in anthrax, he obtained their complete destruction.

In Italy, *Pacinotti* and *Porcelli* have studied the action of Becquerel rays on cultures of bacilli. After exposure to the radiations from uranium, the microbes were deformed, and did not stain in the usual manner. The authors attribute this alteration to a chemical modification of the protoplasm of the bacteria.

The supporters of the opposite view are equally numerous.

Mink, bearing in mind the destructive action of ordinary light, exposed cultures of bacteria to the action of X-rays for periods of thirty and thirty-five minutes without any apparent effect on their vitality. *Wolfenden* and *Forbes Ross*, *Sabrazès* and *Rivière* obtained analogous results with *Bacillus prodigiosus*. *Berton* inoculated guinea-pigs with a diphtheritic culture which had previously been irradiated for periods of sixteen to sixty-four hours. There was no diminution in the virulence of the culture when compared with the non-irradiated culture used in the control experiments.

Scholtz made some interesting observations on cultures of different stages of development. As in *Rieder's* experiments, he used a culture-plate of agar-agar, which he sprinkled with drops of a culture of the typhoid bacillus. This was covered by a sheet of lead, with a central aperture the size of a shilling, and exposed for an hour to the radiations from a soft tube at a distance of 4 inches. In the primary circuit of the induction-coil a current of 4 ampères was employed, and the interruptions were 10 per second. Under similar conditions the same tube had set up a superficial ulceration in a case of lupus, where five exposures of ten minutes each had been given.

The agar-agar plate was then placed in an incubator. After twenty-four hours the culture had grown abundantly over the whole surface, no difference being appreciable between the irradiated centre and the shielded edges.

Identical results were obtained in the course of experiments with the vibrio of cholera and *Bacillus cyanogenus*, which were chosen in consequence of their feeble resistance to other bactericidal agencies.

In order to determine whether the rays might have a greater influence on younger cultures, *Scholtz* repeated the experiment in the following manner: The plate, after inoculation, was placed in the incubator for a period of six hours. A slight uniform growth appeared over the whole surface. It was then exposed to the action of the rays, and replaced in the incubator. The culture developed in the usual manner, and no difference was apparent between the centre and the periphery.

Further experiments were made on cultures of various trichophytic organisms where the growth is much slower. These were irradiated on four successive days for a period of an hour each day. Four

days later the culture had grown over the entire surface of the plate, and during the succeeding days no difference could be observed between the irradiated area and that which had been screened from the radiations.

'It might be objected,' says *Scholtz*, 'that the germs may have been completely destroyed all over the irradiated area, and that the absence of any signs of the action of the X-rays on these young cultivations was due to the fact that they were proliferating very rapidly.'

To settle this question, he devised the following experiment: A culture of the typhoid bacillus on agar-agar was placed in the incubator for forty-eight hours. It was then irradiated in the manner above described. On the following day, and again after a week's interval, a small portion of the growth was removed by a platinum needle, with which a new plate was inoculated. In this experiment also no bactericidal action of the Roentgen rays could be demonstrated.

In another observation small pieces of sterilized blotting-paper were moistened with a fresh culture of *Staphylococcus pyogenes*, and subsequently slightly dried. Of these, some were irradiated for one hour and some for two hours, while others were not exposed to the X-rays. No difference could be detected in their subsequent development.

In some experiments on the bactericidal action of radio-active substances, *Freund*, *Giesel*, and *Walkhoff* obtained negative results. The cultures developed in the usual manner, just as they would have done if they had not been exposed to the radiations. It is probable that the radio-active substances used were not of sufficient activity, for subsequent experiments seem to have established the existence of bactericidal properties in radio-active substances under certain conditions.

How are we to explain these divergences of opinion? Experimental error may be put on one side, for observers like *Rieder* and *Scholtz* are not easily led astray. The cause of divergence must be sought in the quantity of the radiations absorbed on different occasions. Some experimenters exposed the bacterial cultures to a prolonged and intense irradiation, in which case the bacteria were affected. Others, using a less energetic irradiation, obtained no evidence of alteration in their vitality. *Rieder* used a prolonged exposure with a very powerful focus-tube, so that his results are not

in any way comparable with those of other observers under different conditions. In all these cases exact measurements have been wanting, and frequently the degree of penetration of the rays is not noted, a most important cause of divergence in the results of different authors. Often, too, the observer has generalized the results of his experiments without accurately registering the exact details of the technique he employed. The answer cannot be expressed in a simple 'yes' or 'no.' One can only say that under certain conditions of technique the X-rays are bactericidal, whereas under other conditions they are not so. The important point is the dose. It may be concluded with certainty that X-rays do destroy the vitality of bacterial cultures, but in order to do this they must be greatly in excess of the maximum dose permissible in radiotherapy. This is the opinion of *Kienböck*, who asserts that under ordinary conditions of treatment the X-rays have no bactericidal action. While admitting the correctness of *Rieder's* conclusions, Scholtz has also demonstrated that in practice one must not rely on any possible bactericidal action of the rays. The focus-tube used in his experiments was a strong one, and the cultures were irradiated with a dose from fifteen to twenty times that used in radiotherapy, although the quality of the rays was the same.

In practice then, we cannot count on a direct destruction of bacilli, since the quantity of rays necessary to insure this would produce irreparable damage of the patient's tissues. This is, in fact, the only point of practical importance. Heat, light, and other physical agencies are able to destroy microbes under certain conditions; the important point to consider is whether this can be done without at the same time destroying the organism in which they reside.

We have however, no means of knowing whether bacteria are influenced in the same manner when they occur in culture media as when they are disseminated in the foci of a diseased tissue. It may well be imagined that the X-rays have a different effect on an agar plate from that which they exercise on a tuberculous or trichophytic growth.

Muhsam, *Kratzenstein*, *Lortet* and *Genoud*, *Fiorentini* and *Luraschi*, and *Rieder* have experimented on tuberculosis which has been artificially induced. They find that X-ray irradiation diminishes the local reaction, without influencing the general tuberculosis.

Scholtz has devoted a series of experiments to the elucidation of this question. Following *Scheffer's* method, he introduced under the skin of a guinea-pig two threads impregnated with Koch's bacilli, one on the right side and the other on the left side of the animal. The left side was irradiated for ten days, for ten minutes each day; the right side was not rayed. Three weeks after the last exposure the hair on the left side began to come out, and the surface of the skin was raised and swollen, but without any ulceration. The inoculated region had a similar appearance on both sides. An infiltration of the size of a goose-quill appeared around the threads, and this was followed by a subcutaneous abscess. The abscess on the left side was smaller in size, and was slowly absorbed, whereas that on the right side broke down and discharged.

On both sides the inguinal glands were enlarged to the size of a pea.

The animal was killed six weeks after the inoculation. Tubercle of the spleen was found, and on both sides the inguinal glands had undergone caseous degeneration, and contained Koch's bacilli. Both to the naked eye and to the microscope the appearances in the inoculated regions were identical. All that could be said was that the inflammatory reaction was less marked on the irradiated side. No tubercle bacilli could be found at the seat of inoculation on either side.

Schultz concludes in these words: 'Under ordinary therapeutic conditions I could not detect any appreciable influence of the X-rays on tuberculosis experimentally produced by subcutaneous inoculation.'

Sabouraud has experimented on cases of tinea. He made a culture from the hairs which were shed during epilation by X-rays. We have ourselves examined these cultures, which showed as great vitality as if they had been made from hairs which had been epilated by tweezers.

In the *American Journal* of January, 1903, *A. G. Ellis* supports the same view, and asserts that the X-rays have no parasiticidal action, and that the good effects of radiotherapy are not due to any destructive action.

It is well known that irradiation with X-rays will cure lupus, and causes a complete disappearance of the bacilli, but here we must carefully distinguish between their primary and secondary action.

The X-rays do not destroy the bacilli directly. The process of degeneration in the lupus nodules sets up an inflammatory action, which is concentrated precisely in the foci of disease, and results in the destruction of the microbic colonies.

We may therefore agree with Holzknecht: 'The cure of an infective process is not due to any bactericidal action of the X-rays, since the bactericidal dose is many times as great as the curative dose.'

CHAPTER IV

PATHOLOGICAL ANATOMY

In order properly to appreciate the action of the Roentgen rays on the tissues of the body, and more especially on the skin, it is important to study the histological changes which are produced by an irradiation. One should understand the action of the rays—what structures are first affected, what alterations are set up, and the exact processes of reparation. By this means we may hope to determine the particular morbid conditions in which X-rays may be expected to be beneficial, and to distinguish those in which their action would be manifestly hurtful.

And, first, we will consider the histological modification of healthy tissue under the action of X-rays.

From the very commencement of radiography accidental dermatitis has occurred, and a certain number of microscopic observations have been made. The results however, were not of any very practical service, and the reports of cases were principally a record of the appearances visible to the naked eye.

At a meeting of the Medical Society of Vienna in 1898 *Kaposi* gave the following opinion : 'The principal effect of the Roentgen rays is on the vascular tension, consisting of vaso-dilatation and a consequent stimulation of the circulation. There is also a certain amount of inflammatory infiltration of the cell elements, and more especially of newly-formed tissues, which undergo an alteration of their molecular composition, or a fatty degeneration with subsequent absorption.'

Neïsser also noticed a specific action on the vessels. 'In the so-called dermatitis the old idea of a simple inflammatory reaction has been proved to be false ;' and *Weigert* was correct in his opinion that all the phenomena are due to a primitive lesion of the vessels, consequent on the inflammatory reaction. The necrosis following

irradiation by X-rays is most probably due to some slight alteration of the vessels. In his opinion the cure of lupus also is due to a hyperæmia, which facilitates the cicatrization of the lesions and the absorption of the tubercular foci.

In *La France Médicale* for 1898 *Oudin*, *Barthélemy*, and *Darier* published a report of some histological examinations of tissues taken from guinea-pigs which had been exposed to the X-rays.

In *Apostoli's* case the slough which had separated from a large abdominal ulcer was carefully examined by *Darier.* The microscope showed the usual appearance of dry gangrene. There was no sign of anything exceptional in the vessels or nerves. The gangrene of the skin and the subcutaneous tissue was complete—that was all.

Following this observation, *Oudin* and *Barthélemy* subjected a number of guinea-pigs to intense irradiation. Alopecia resulted, followed by the appearance of phlyctenulæ and crusts. A careful histological examination was made, with the following results:

'The hairs which fell out showed no signs of atrophy of the bulbar portion. The bare skin showed widespread lesions of the epidermis and of the hair follicles. The dermis and the vessels were not notably affected.

'The thickening of the skin in all its layers, the enormous increase of eleïdin (keratohyaline), and the marked atrophy of the hair follicles, may be explained as the result of a process of reaction against a very unusual irritant. This irritant appeared to increase the vitality of those elements of the skin which were least differentiated, without producing any signs of necrosis in them. On the contrary, the more highly differentiated elements—glands, hairs, nails, etc.—were partially atrophied. It was impossible to understand the exact mechanism of this atrophy, whether due to necrosis, vascular disturbance, obliteration, or other causes.

'In the case of the guinea-pig, it is interesting to notice that the aspect which the skin assumed in consequence of this irritation is somewhat similar to the normal texture of the skin in certain parts of the animal's body. For instance, in the pad of the guinea-pig we find the epidermis bare of hair and glands, thickened, and with a granular layer rich in eleïdin, the only noticeable difference being the presence of vestigeal remains of the hair follicles in the shape of epidermic cones, and in the greater irregularity of the eleïdin and the papillæ.'

In his experiments on the radiodermatitis of the rabbit, *Jutassy* came to the same conclusions.

Unna had the opportunity of examining a portion of human skin which had been irradiated on several occasions, and which only presented to the naked eye an appearance of slight erythema and pigmentation. By special methods of staining with picro-carmine, orcein, fuchsin, etc., he found that the collagenous fibres of the connective tissue had become 'basophile.' From this he concluded that the collagenous tissue was primarily affected by the rays, and that in the process of degeneration it set up a slowly progressing inflammatory reaction.

Gassmann examined the skin of a patient suffering from a deep X-ray ulcer. The most superficial layer was found to consist of a mass of necrosed tissue, mingled with cocci, with no trace of organization. In the deeper layers were found colourless fibrillary masses, accompanied by a number of leucocytes and nuclear débris. The vessels of the dermis and of the hypodermis exhibited vascular degeneration of their internal and muscular coats. This latter lesion, in his opinion, accounted for the slow progress of healing in this variety of ulceration.

Lion made a number of microscopic examinations of portions of healthy skin which had been slightly irradiated, and which exhibited no change of appearance to the naked eye. In these cases he found merely a slight alteration in the walls of the palisade layer of the epithelium. Pursuing his researches, he made several preparations of the ulcerating tissue resulting from X-ray burns of a previously healthy skin. At the margin he found the corneal layer swollen, and the Malpighian layer diminished in thickness and filled with vacuoles throughout its whole depth. The cells were swollen, and appeared as if perforated; the interstitial substance was increased in quantity, and full of irregular lacunæ.

In the papillæ the smaller vessels were enlarged and full of blood, while their walls were thinned, and had many vacuoles, as described by *Gassmann*. The larger vessels showed signs of endothelial proliferation. The endothelium itself, as well as the connective tissue of the vascular wall, was the seat of considerable vacuolization. In addition, the bands of fibrous tissue were ill-defined, and hyaline in structure.

Ehrmann of Vienna is of opinion that the hyperæmia is due to

the direct action of the X-rays on the capillaries. The walls become altered so as to permit the passage of the blood globules: a diapedesis occurs rather than a hæmorrhage. At the same time there is an exudation of serum containing hæmoglobin in solution. This it is that causes the yellow hue of the hyperæmic skin. At the same time a golden yellow pigment, hæmosiderin, is precipitated in the interstices of the tissues. The skin retains the brownish-yellow colour due to this pigment for many weeks, after which it may be ultimately absorbed.

In some instances the skin may contain a large number of melanoblasts, or cells containing black pigment. When such a skin is submitted to the action of X-rays, the pigment cells may deposit melanin, giving a sepia-coloured tint to the skin, which may remain for years. This melanin is totally different from hæmosiderin, the former remaining within the melanoblasts, while the latter is deposited in the interstices of the tissues.

Oscar Salomon excised a piece of ulcerated tissue due to an X-ray burn. A microscopic examination showed lesions resembling those of idiopathic scleroma—viz., degeneration of the papillæ, hypertrophy of the collagenous tissue, and thickening of the walls of the vessels, which were surrounded and infiltrated with leucocytes. At the deeper part of the ulcer the elastic tissue was quite normal. Nearer the surface, however, numberless fibrillæ were observed, short, fine, and slightly undulating, generally parallel, mostly running in a vertical direction, and easily stained by the Unna-Taenzer and Weigert methods.

These fibrillæ became more numerous as they approached the sub-epidermal zone of cellular infiltration. Similar fibrillæ were apparent on the thickened sheath of the bloodvessels, running in a direction parallel to the vessels.

In these observations there is a certain amount of divergence. Most of the specimens have been excised from the margins of deep ulcerations, and give but a vague idea of the true histological processes occurring in the course of a radiodermatitis.

Scholtz has given the greatest attention to this subject, and has made systematic microscopic examinations. For this purpose he chose the skin of the pig, as most closely resembling that of the human subject, and also because it reacted in a similar manner to irradiation.

Scholtz, moreover, carried out his histological examinations at

each successive stage of the reaction, under conditions analogous to those obtaining during the course of radiotherapeutic treatment. The animal was of some considerable size, and it was exposed to the usual therapeutic doses of X-rays. His results are, therefore, far more important than those of some other observers, who experimented on guinea-pigs or rabbits, and used doses far in excess of any which could possibly be employed in practice.

We will proceed to describe some of the more important of these experiments.

The pieces of skin excised were partially hardened in alcohol, and afterwards fixed by means of firmol, sublimate solution, and Fleming's solution, being finally hardened in absolute alcohol. They were then enclosed in paraffin or celloidine. Hæmatoxyline-eosin, polychrome blue, methylene blue, and safranine were used to stain the nuclei and protoplasm. The connective tissue was stained by the methods of *Giesen* and *Unna*, in order to show the collacine and collastine.

Experiment I.—The observation was made on the skin of the back of a young pig. A small area was irradiated for an hour, at a distance of 6 inches from the anticathode. Twenty-four hours afterwards the piece was excised. There was no modification of the skin visible to the naked eye. Under the microscope there was no well-marked alteration either in the true skin or in the epidermis. The protoplasm of the cells of the prickle layer was more highly coloured than normal, and the contours were not so well-defined. By Kromayer's method the intercellular processes were readily stained.

Experiment II.—The time of exposure being the same, the irradiated area was excised after an interval of seven days. To the naked eye there was no marked alteration, except that the hairs were fragile and were beginning to be shed.

On microscopic examination the cells of the corneal layer were found to be more or less dissociated, and here and there cells with a coloured nucleus appeared. The granular layer had almost disappeared, only faint traces remaining. The prickle-cell layer was notably thinned. The cells themselves were modified in form, greatly swollen, and with ill-defined contours, and their volume was increased, even in the palisade layer. The protoplasm was strongly stained by hæmatoxylin, but the colour was diffuse. The nucleus, on the contrary, was but feebly coloured, and the chro-

matin was broken up into small fragments and débris. Most of the nuclei were swollen, dentate or vacuolized. Vacuoles also appeared in the protoplasm, especially in the neighbourhood of the nuclei.

In every microscopic field cells were to be seen whose nuclei had undergone repeated fission. There was no evidence of karyokinesis —or, at all events, only the commencement of the process. As one passed from the basal to the corneal layer, the phenomena of degeneration increased. Near the surface the cellular outlines were barely visible, their protoplasm being fused into a homogeneous mass, and their nuclei very faint. The hair follicles had undergone a similar degeneration, which accounted for the fragility and shedding of the hairs.

The dermis was slightly œdematous, and the trabeculæ of the connective tissue were indistinct and slightly swollen. In the subcutaneous tissue there was no alteration in the normal colour reaction. On employing *Unna's* method of staining for collacine and collastine, no basophile reaction was observed. The network of elastic fibres was intact.

There was no alteration in the vessels of smaller calibre, with the exception of some slight indications of inflammatory action.

The connective tissue cells were slightly modified. They were swollen, sometimes abnormal in form, and their protoplasm stained uniformly.

The same evidence of slight commencing degeneration was observable in the sudoriparous glands. The cells were proliferating here and there, and blocking the excretory canal.

In the larger bloodvessels degenerative lesions had made their appearance. These occurred in the middle coat, but were more frequent in the internal coat. The cells of the latter were swollen, and projecting into the lumen of the vessel; while some of them were proliferating and disintegrating, and were at the point of being washed away by the blood-stream.

Experiment III.—The skin on the back of a young pig was irradiated for fifteen minutes, at a distance of 6 inches, on nine consecutive days. The irradiated area was excised twenty-four hours after the last exposure.

To the naked eye the skin appeared slightly erythematous and atrophic, and the hairs were beginning to fall out.

Under the microscope the modifications of the skin were similar

to those described in Experiment II., but much more marked. Signs of inflammatory reaction were noticeable. A slight infiltration of leucocytes and some polynuclear cells were visible around the vessels of the true skin, and in the Malpighian layer a certain number of migratory cells were apparent. The smaller vessels of the papillary bodies were slightly dilated.

Experiment IV.—The ear of a young pig was irradiated daily for eleven days at a distance of 6 inches, for fifteen minutes each days. Six days after the last exposure a small portion of the border of the ear was excised.

The hairs had been shed on both the outer and the inner surface of the ear, and the skin beneath was red and atrophic. In the middle of the external surface of the ear there was a slight phlyctenuloid elevation of the epithelium.

Under the microscope the appearances of degeneration were similar to those of Experiments II. and III., only more advanced. There was sharp inflammatory reaction, with abundant migration of polynuclear cells. Numbers of leucocytes were travelling towards the epidermis. Some of these had already penetrated into the interior of the degenerating cells, and were acting the part of veritable phagocytes. In the midst of the pus globules were found a number of so-called 'mast-cells' charged with granules.

In the centre of the irradiated area the corneous layer was raised, and beneath were masses of leucocytes closely packed together.

Where the skin had been most affected by the rays, and the surface was discharging, the corneal layer had disappeared completely and an ulcerative process had begun.

The network of elastic fibres was still intact, but did not stain so well. The cartilage of the ear was not attacked, and the subcutaneous tissue had undergone changes similar to those in Experiment III.

In the hair follicle the epithelial sheath had undergone a process of degeneration exactly similar to that which was observed in the Malpighian layer. The whole hair follicle is thus destroyed little by little and replaced by masses of leucocytes.

Experiment V.—The skin of the back of a pig was irradiated by X-rays during nine days, for a quarter of an hour each day, at a distance of 6 inches. The exposed area was excised eight days after the last exposure.

The skin had begun to discharge four days after the final exposure. It was covered by a thin fibro-purulent membrane, and was superficially necrosed. The appearance of the lesion resembled that of a septic burn of the second degree, after the blisters have disappeared.

The histological appearances were the same as the preceding. The corneal and Malpighian layers had completely disappeared. In their place was a collection of polynuclear leucocytes enveloped in a fine network, with cellular and nuclear débris in the interstices. Here and there a fine fibrinous network could be demonstrated by Weigert's method. Above this collection of leucocytes was a thin layer, composed of disintegrated pus globules, the remains of nuclei, and a collection of bacilli and micrococci staining deep violet by Gram's method.

The scab of an ulcer caused by radiodermatitis was thus formed of the remains of leucocytes, cellular and nuclear débris, and bacteria. On the lower side it was clearly differentiated from the skin at certain points, whilst in other parts it was continuous with the subjacent infiltration of the connective tissue.

The papillary body was easily recognised, and retained its configuration unimpaired.

The fibres of connective tissue in the neighbourhood of the slough were swollen and infiltrated with serum, and even broken down in places. The network of elastic tissue was still entirely intact.

The connective-tissue cells were degenerated, and their protoplasm was swollen, staining in a diffuse manner; the nuclei only stained with difficulty, were irregular in shape, and often multiform. The medium-sized vessels showed signs of cellular degeneration in their inner and middle coats. The cells of the internal coat were proliferating and detached, with vacuolization of the wall of the artery, as described by *Gassmann* and *Lyon.*

The smaller vessels were dilated, filled with blood, and surrounded by leucocytes. Here and there, in the collection of leucocytes, or in the dermis itself, were foci of hæmorrhage of greater or lesser size.

The cells lining the sudoriparous glands showed degenerative changes. The hair follicles and sebaceous glands were entirely destroyed. In their place was a mass of leucocytes, mingled with the débris of nuclei and fibrillæ.

Scholtz has also studied the course of reparation in these ulcers, basing his observations on the human skin. He says:

'The infiltration of the dermis disappears, the connective-tissue cells regain their normal appearance, and where the papillary layer has been destroyed, it is renewed as a horizontal layer, much thinner and finer than before. The epidermis begins to be regenerated at the margin of the wound, covers in the papillary layer, and sends prolongations downwards between the papillæ. The skin is completely renewed, with the exception of the hair follicles and the sebaceous follicles.'

Although the process of repair appears to be complete, the new tissue for some time retains certain abnormal characteristics. The appearance which the cells presented at the commencement of the radiodermatitis persists for some considerable time. This fact explains the special sensibility of the irradiated skin to the X-rays and other irritating agents.

In America and elsewhere numerous histological studies have been made on this subject. Most of these, however, relate to tumours or carcinomatous lesions treated by X-rays. We shall return to them later on.

According to the views of *Pusey*, the primitive action of the X-rays is on the epithelial cells themselves, since the alteration in their structure is apparent long before there is any visible lesion of the bloodvessels. Cellular alteration was early produced in all tissues, whether neoplastic or normal, with varying intensity and rapidity. Only in the latter stages do modifications of the local circulation intervene.

Professor von Bruno of Tubingen also admits the selective action of X-rays on the cells of epithelial tissue. It is to this characteristic that one may attribute the action on cancer, as we shall see later on.

Recent experiments by *Albers Schönberg* and *Freiben* seem to show that, at all events in the guinea-pig, the X-rays act on the cells of the testicle as well as on the elements of the cutaneous tissue. They seem to have the property of producing degeneration of the epithelium of the spermatic ducts, and consequent complete azoöspermia. It is of importance to discover if the results are identical in the case of the guinea-pig and in the human subject, and, moreover, if the results follow an irradiation such as may be given during a course of radiotherapy. It is well known that

apparently opposite results may be obtained, according to the quantity of the rays absorbed and the size of the animal used in the experiment.

We have not ourselves verified *Scholtz's* histological results. It seemed to us more useful to devote our time to the therapeutic experiments, more especially as *Scholtz's* work seemed to be carried out with the highest precision.

It is, nevertheless, certain that the histological results hitherto obtained are not entirely conclusive, and that the greater part of the modifications above described may possibly be the result of an irritant other than the X-rays.

We will close this chapter by a résumé of *Scholtz's* conclusions:

1. The Roentgen rays exercise their chief influence on the cellular elements of the skin. The cells are attacked first, and undergo a slow process of degeneration, whilst the connective tissue, the elastic tissue, the muscles and cartilage are but slightly affected, the change in these tissues being secondary to the cellular degeneration and to the inflammatory processes of reaction.

2. The degeneration primarily attacks the cells of the epidermis; afterwards, in less degree, the gland cells, and those of the muscles and connective tissue.

3. The phenomena of degeneration are variable, and extend to the nucleus as well as the body of the cell.

4. When the process of degeneration has attained a certain degree, phenomena of inflammatory reaction set in. These are manifested by dilatation of the vessels, serous infiltration of the tissues, and a migration of the leucocytes, which often results in considerable infiltration.

Wherever a considerable degree of cellular degeneration occurs as a consequence of intense irradiation, the leucocytes flock thither *en masse*, and aid in the complete destruction of the injured tissue.

5. The lesions, both of the larger vessels and of those of smaller calibre, play a most important part in the production of the Roentgen ulcer, and explain the extremely slow course of its reparation.

CHAPTER V

PATHOLOGICAL PHYSIOLOGY

This chapter must necessarily be more or less a chapter of hypo theses, for we meet with enormous difficulties when we endeavour to penetrate into the intimate life processes of an individual tissue To explain satisfactorily the phenomena consequent on an exposure to the X-rays, we should know the biological properties of the radiations, and the modifications of cell-life due to their influence, both of which are completely unknown to us.

C. E. Gillaume was the first to explain these modifications of cell-growth by supposing that the organic liquids are decomposed by a sort of electrolysis, and that it is the acids and bases thus set free which disorganize the tissue. This hypothesis is not admissible, for as we have already shown, radiodermatitis is the result of the X-rays themselves, and not of the electrical discharges, without which no electrolysis is possible.

Gassmann considers the cause of the lesions to consist in a primary alteration of the vessels, which results in necrosis of the tissues. The pathological observations brought forward in support of this view are opposed by the researches of *Scholtz*. The results have been attributed to a number of hypothetical causes—to the occurrence of local spasms, to acute anæmia, to passive congestion, etc. None of these however explain the occurrence of late and deferred lesions, or the long period of latency which precedes reaction. According to *Unna*, the X-rays are able to act only on the connective tissue of the skin, 'the most indolent of all tissues,' and hence the slowness of evolution and reaction.

Another explanation proposed is that the living cell is destroyed by the coagulation of its albumin. Now, *Oudin* says the X-rays do not destroy microbes, or do so but feebly. There are, therefore, some cells whose albumin is coagulated by X-rays, and others on

which they have no action. This theory, again, does not explain the occurrence of the late lesions, appearing, it may be, months after irradiation, since during this long interval of time all the cellular elements will have been replaced by new ones.

A more reasonable hypothesis is that put forward by *Oudin* in 1897. With *Barthélemy* and *Darier*, he believes that the cutaneous symptoms may possibly not be primary, but a degeneration secondary to an injury to the trophic nerves of the irradiated area. The immediate action of the radiation is on the subcutaneous nerve cells. This is followed by an ascending irritation of the nerve fibres in connection with the injured cells; then follows a centrifugal neuritis, and consequent mortification of the tissues.

On this hypothesis there would be a close analogy between ulcerations due to tropho-neurotic neuritis and those due to X-rays.

Oudin says: 'How, except by the intervention of a secondary neuritis, can one explain a case like that of Apostoli? More than a year after the occurrence of dermatitis a large cicatrix began to break down, the ulceration recommenced, and the whole series of primary dermatitis was reproduced. All this occurred without intervention of the smallest injury or irritation to the part. How else can we explain the occurrence of late lesions without any local symptom which would lead one to suspect such serious complications? Let us take the case in which the lesion follows the ordinary course. The superficial redness is seen on the second day; it remains stationary for a period of eight to fifteen days, then vesicles appear, and later on phlyctenulæ, which soon begin to ulcerate. It is only at the end of fifteen days or a month that one is able to estimate the degree of severity of the lesions resulting from an X-ray irradiation, and that one finds the tissues beginning to mortify. Occasionally even long after this, new and unexpected sloughing sets in around the primary lesion.

'One is struck by the similarity of these phenomena with those of peripheric neuritis following on injury. From two to four weeks, or even longer, after the injury a cutaneous lesion sometimes appears which strangely resembles a Roentgen ulceration. It is true that in an X-ray dermatitis we do not get the anæsthesia and muscular atrophy which characterize a tropho-neurosis of traumatic origin. In the latter case however the injury, section, or bruising of the nerve involves the whole of the nerve trunk,

with its motive, sensitive, and nutritive fibres. We may imagine in the X-ray dermatitis a specialized action of the irritant, affecting the trophic terminations of the nerves in the sub-epidermic layers, and hence the sympathetic nervous network which presides over nutrition.

'It cannot be said that the sensitive fibres entirely escape injury. It is true there is no anæsthesia, but we often find painful sensations of great intensity, which are not limited to the ulcerated region, and may extend to distant parts of the body, which are innervated by the same nerve supply as the area which has been irritated by the rays.'

At the Congress of Medicine at Montpelier *Bertin-Sans* and *Rodet* exhibited the spinal cords of a number of guinea-pigs, showing the specific anatomic modifications of meningo-myelitis.

Briaux and *Morat* reported the results of similar experiments to the Society of Sciences at Lyon in May, 1897. These were observations on trophic disturbances following section of the posterior roots of the lumbar nerves. Three separate experiments were made on dogs. A section was made of the roots of the two last lumbar nerves and of the anterior nerve on one side, at a spot between the ganglion and the spinal cord. Two months afterwards trophic disturbances made their appearance in the feet, an ulceration like that of perforating ulcer set in, and the hair fell out. The section of the anterior nerve roots only was not followed by any trophic disturbances, thus showing, in the author's opinion, that these were due to the lesion of the posterior roots. The integrity of the spinal ganglion and of the sensitive nerve trunk does not prevent the ulceration.

This explanation accounts very satisfactorily for the occurrence of late lesions, but it does not fit in so well with the ordinary course of reaction. The lesions of slow evolution are exceedingly rare. It is difficult to understand how a tropho-neurosis could cause the more ordinary symptoms of erythema, infiltration, and vesiculation in so short a time. A primary inflammatory phase must almost necessarily intervene between an injury and the trophic results. Moreover, in many instances the whole reaction disappears in the course of ten or fifteen days, and the process of repair is complete. Again, in certain varieties of ulceration the X-rays seem to exercise a stimulant action, and to facilitate the process of healing. As yet we have had no

corroboration of this hypothesis from an anatomical or pathological standpoint.

In opposition to this view are the results communicated to the Congress at Berne in 1902 by *Sala* of Pavia of his experiments on rats and guinea-pigs, in order to determine whether the alterations in the skin were due to lesions of the nerves of the periphery, or of the central nervous system.

A histological examination of the animals after death failed to reveal any alteration either in the spinal cord or in the peripheral nerves.

A novel hypothesis was propounded by *H. P. Pratt* at the American Congress, in which he explained that the X-ray burn was caused by air-borne microbes which were driven into the tissue, and that these burns might be entirely obviated by the interposition of a screen of celluloid a tenth of an inch thick.

Skinner, however, has produced an X-ray burn by an irradiation through a surgical dressing, and the interposition of an aluminium screen, much less of a celluloid plate, will not prevent the occurrence of reaction.

A more complete hypothesis is that given by *Professor Leduc* of Nantes. We quote *Mdlle. de Pisareff*, who received the explanation from himself:

'The Roentgen rays, in common with all rays which are capable of impressing a photographic plate, have the property of discharging a negatively electrified body. Since it conducts electricity, the human organism may be considered as an electrolyte—*i.e.*, a dielectric liquid in which float a number of ions, some carrying a positive and some a negative charge of electricity. If the same phenomena occur in liquids and in the living body as in air, we must allow that the chemical rays, as well as the Roentgen rays, have the power of discharging the negative ions, which thus pass into the state of elementary atoms. This process must necessarily disturb the chemical equilibrium of the solution.

'An analogous phenomenon takes place on the photographic plate. Here we have two varieties of ions: the silver ions, charged positively, and the bromine ions, charged negatively. The latent image results from the discharge of the negative bromine ion, which is set free as an elemental atom. This causes a disturbance of chemical equilibrium, which is rendered manifest when the plate is developed, the chemical reactions of the impressed portions

being totally different from those which have been shielded from irradiation. Just as the image exists in a latent state on the photographic plate till the developer reveals it, so an alteration of chemical equilibrium exists in the tissues which may be manifested after considerable delay by the occurrence of late lesions. In this tissue of unstable equilibrium, disturbances of nutrition may play the part of the developer of the photographic plate.

'From another point of view one may compare the action of X-rays on a living tissue to that of an unoxidizable anode, which discharges the negative ions, sets them free, and produces secondary reactions resulting in the destruction of the tissue. An acid radicle—like chlorine, for example—may exist harmlessly enough as an ion in the economy. When it comes into contact with an anode it loses its negative charge, is set free as an element in the nascent state, and attacks the tissues violently, taking away hydrogen to form hydrochloric acid, and setting free gaseous oxygen.'

Mdlle. Pisareff considers that the experiment recently designed by *Professor Leduc* to support this view in reality rather disproves it. Two metallic plates connected in circuit with a galvanometer are immersed in an electrolytic liquid. If a pencil of X-rays be directed on to one of the plates, a difference of potential should result in consequence of the discharge of the negative ions. This effect has not been observed.

M. Leduc then explains the reaction of the X-rays as due to chemical action. *Kienböck* had already put forward a similar hypothesis. According to his theory, radiodermatitis is due to a chemical modification of the tissues, produced by the X-rays absorbed. He says: 'The analogous dermatitis following exposure to the sun's rays or the light of an arc lamp is due to the transformation of actinic into chemical energy. The ultra-violet rays have a further resemblance to X-rays: they excite phosphorescence and fluorescence, they reduce bromide of silver, they influence the germination of seeds, and, under certain conditions, they may arrest the growth of bacteria.

Kienböck considers that under the influence of the rays abnormal toxic substances are formed in the cells themselves. The long period of latency is due to accumulation of noxious products in the tissues, which, after a certain lapse of time, become sufficient to produce reaction. The poisonous substances or toxins may be either

abnormal products, or normal products, resulting from altered metabolism, which in the ordinary course of events are rapidly absorbed by the cells.

The symptoms of general intoxication, fever, headache, nocturnal delirium, etc., which follow the invasion of toxins, are also sometimes met with in the course of an acute radiodermatitis. 'In this case,' says *Kienböck*, 'the toxins are formed in the injured tissues, and the general intoxication results from the passage of these toxins into the general circulation.'

Numerous observations attest the possibility of an alteration, temporary or permanent, in the activity of the cellular elements. Warm-blooded animals are much more sensitive to X-rays than cold-blooded animals, as may be seen by comparing their action on the mouse and the frog. Young subjects react more rapidly and more violently than adults, and these are more sensitive than the aged. Organs moreover, like the skin, hairs, etc., in which the cells are undergoing active cellular proliferation, are more sensitive to the action of the rays than other tissues.

Kienböck thus concludes: 'In Roentgen dermatitis we recognise a reaction of the cells of the tissue, penetrating to the depth of the skin, followed by disturbances of nutrition of chemical origin due to the absorption of the rays.'

Pusey in America thinks that the ill effects are due to the actinic properties of the Roentgen rays. 'They are,' he says, 'analogous to the actinic properties of light. Like the ultra-violet rays of the spectrum, the Roentgen rays are invisible, but excite fluorescence in certain substances, and produce similar inflammatory lesions in the skin and subcutaneous tissue.'

Lépine and *Boulud* have shown that X-rays, under certain conditions, modify both the glycogenic and also the glycolytic functions of the liver. Some authorities think that the action on the organism may be due to some special modification of glycogen.

Schwartz of Vienna has demonstrated that lecithin is rapidly decomposed by the rays, and considers that their pathogenetic effects may be due to this action. To prove this, however, it would be necessary to show that the tissues most inimical to the rays were precisely those which contained the greatest amount of glycogen or lecithin.

According to *Ulmann*, X-ray dermatitis is due to a chemical alteration of the tissues. As in the case of ultra-violet rays of

light, the actinic energy of the X-rays is transformed into chemical energy when these are absorbed by the tissue. There is a consequent production of toxins which may cause serious necrosis, with an occasional rise of temperature. The number of these hypotheses of itself indicates the difficulty of the problem.

It seems proved that the X-rays are able to set up chemical alterations in the tissue, the manifestation of which is more or less retarded according to circumstances. This explanation is reasonable enough. There is a rising tendency at the present time to classify the Roentgen rays with ultra-violet rays of light, the ethereal vibrations which most resemble them ; and it would not be surprising if the reactions they produce were due to a similar cause—*viz.*, their actinic energy. From a biological standpoint the X-rays might then be regarded as the most powerful variety of light.

Although the actinic energy of the X-rays may be regarded as analogous to that of ultra-violet light, the two are by no means identical. The former must be a special form of actinic energy, since it is able to determine in the tissues reactions particular to itself, as, for instance, the well-known lesions of slow evolution. Moreover, the fact that sunlight and X-rays have opposite effects on the coloration of certain salts, the one decolorizing and the other coloring them, shows us that, although analogous, these two agents are not identical.

CHAPTER VI

RADIOTHERAPY

The burns and other accidents which sometimes result from repeated exposure to X-ray irradiation are always inconvenient and sometimes disastrous. Were we not able to obviate them with almost complete certainty, radiotherapy would have remained a dangerous and empirical art. It would have continued to be a curiosity of the laboratory, and would never have evoked the enthusiasm with which it is greeted to-day. Fortunately, at the present time we can regulate the action with approximate accuracy, thanks to the recent discoveries of physicists, to the instruments of exact measurement which have been devised, and to the scientific technique which has been evolved. At most we may get a slight amount of redness or vesiculation, but ulceration or sloughing is no longer to be feared if we employ exact measurement—in a word, if we know exactly what we are doing.

It must never be presumed that the employment of X-ray irradiation will be free from all possible danger. Any powerful therapeutic agent is capable of producing injurious effects even when employed with method and with all possible precautions. These may be due to a special idiosyncrasy of the patient, or to some particular condition difficult to determine. Cases of this kind constitute the exception, but occasionally occur in the course of radiotherapy.

In the whole course of our experience of X-rays in the treatment of skin disease, we have never had a severe case of dermatitis. Now and again the reaction has overstepped the desired degree, but we have had no reason to deplore one of those terrible cases of radiodermatitis which are at once the despair of the patient and the reproach of the practitioner.

In this chapter we shall discuss the various factors which must be taken into consideration in the practice of radiotherapy. In order to succeed, and still more in order not to injure the patient, all of these must be carefully weighed, although they may not all be of the same importance.

Radiotherapeutic treatment then includes two principal factors —the active agent and the patient.

We will first consider the part played by the patient, the sensibility of his tissues, the disease from which he is suffering, and the reaction desired.

In the next place we will examine the factors which influence the dose of the active agent—the X-rays. This is a most important branch of the subject, and includes a consideration of our means of exact measurement.

1. *Factors Relating to the Patient.*

Reaction is Proportional to Quantity of X-Rays absorbed.—*Kienböck*, in his study of the X-rays on the skin, thus sums up the question: 'The degree of reaction depends essentially on the quantity of rays which strike the skin.' In other words, the modification which the irradiated tissue undergoes is proportional to the quantity of rays absorbed by it. As *Béclère* has pointed out, this law may be extended to cases involving the irradiation of the deeper organs of the body.

It is only true, however, so long as the quality of the rays remains unaltered—*i.e.*, so long as they maintain their initial degree of activity. It is evident that a large quantity of highly penetrating rays will produce a stronger reaction than a small quantity of less penetrating rays.

The second law is that the duration of the period of incubation varies in inverse ratio to the strength of the dose.

Kienböck proved this experimentally in the following manner: A cutaneous area was irradiated by a focus-tube placed at a short distance from the surface. The reaction commenced at the point nearest to the anticathode, where the quantity of rays absorbed was a maximum. For the same reason the radiodermatitis was most marked at the centre, the reaction gradually fading away towards the circumference. On the other hand, the processes of repair began at the circumference, and spread towards the centre.

The mathematical reason for this effect is described in the chapter which deals with the measurement of X-rays.

As shown by *Danlos*, the radiations from radio-active substances furnish additional proof of the truth of this law. In this case the source of the radiations was evidently not subject to variation, and the distance from the skin was kept constant. Under these conditions, it was found that the severity of the lesions was strictly proportional to the time of exposure—*i.e.*, to the quantity of rays impinging on the skin.

In radiotherapy one should endeavour to irradiate the tissue with the exact quantity necessary to produce a definite result.

The dose necessary for the production of an alopecia will naturally be less than that required for the destruction of an epithelioma. In the use of other therapeutic agents we are often obliged to vary the dose. A given drug may have a tonic action in a small dose, an emetic action in a moderate dose, and a poisonous action in a large dose. The same may be said of the X-rays. Take for example their action on the scalp. In small fractional doses they have a stimulating effect on the hair, producing an action similar to that of a rubefacient lotion, whereas in large doses they cause epilation, and in still larger doses vesiculation, ulceration, and sloughing.

What is the therapeutic dose of the X-rays? The answer to this question depends on a number of factors, the most important of which is the nature of the lesion. In another chapter we shall endeavour to discuss more fully the doses of X-rays which we have found to give the best results. Here it is sufficient to note that any exposure likely to cause dermatitis is greatly in excess of that necessary to produce epilation. Taking this last quantity as unity, a dose of 5 units will set up a moist inflammatory reaction, and 10 to 20 such units will probably produce an obstinate ulceration. In our opinion these numbers are much too high, and the operator who trusts them implicitly will probably have to regret the occurrence of accidental dermatitis. In fact, the quantity of X-rays required to produce alopecia is very indefinite. An epilation does not occur in the same manner in different individuals, and varies, moreover, in different parts of the body. On the hairy scalp the results are rapid and very satisfactory; whereas on the lips and cheeks they are slow, and often most disappointing.

Idiosyncrasy.—It may be of interest to inquire whether certain individuals possess a special idiosyncrasy in regard to the action of X-rays, as might be surmised from the fact that the effect of an identical dose varies so greatly in different cases. The question resolves itself into this: Can a dose which in one person is only sufficient to set up slight redness, produce in another individual a severe dermatitis?

Ever since the first introduction of radiotherapeutics the existence of a special idiosyncrasy has been the favourite hypothesis to account for X-ray burns. It was not thought necessary to seek further for the cause of the dermatitis, as it was much easier to attribute all accidents to a predisposition on the part of the patient.

Nearly every author who studied the X-rays in the early days of radiotherapy speaks of this idiosyncrasy. *Oudin* says: 'The question of idiosyncrasy has always played an important rôle in the accounts of X-ray burns. At a time when the subject was but little understood this was a convenient way of throwing on the patient a portion of the responsibility. Idiosyncrasy was the defence of the operator against the patient—a defence, be it said, neither scientific nor honest.' This is perhaps too severe. It is too much to assert that there is no such thing as idiosyncrasy. Nevertheless, *Oudin* is near the truth when he remarks: 'One had to admit the existence of idiosyncrasy, because one could not imagine any other efficient cause of the accidental dermatitis.' He goes on to say: 'In co-operation with *Dr. Barthélemy*, I have made a long series of observations on this question. For this purpose we made choice of subjects of the most varied constitution, differing in the coloration of the skin and hair, and also in temperament. These we submitted to irradiations of similar intensity for radiographic purposes. We came to the conclusion that there is no evidence that some individuals have a special vulnerability to the action of the X-rays. The most that can be said is that of two subjects equally irradiated, the weaker and less resistant will have a little stronger reaction.'

Kienböck's opinion is in the same sense, though less emphatic: 'A special predisposition of the individual does not enter into the question of X-ray dermatitis. I feel sure that in the great majority of cases the cause is to be traced to hyperexposure. This is the origin of every case of Roentgen ulcer hitherto published. We are

therefore justified in denying the existence of a special idiosyncrasy, in the sense that the same intensity of irradiation will produce a slight erythema in a normal person and a severe ulceration in another who has this special predisposition.

In 1904, at the Congress of Grenoble, *Kienböck* repeated this opinion: 'Apart from slight differences due to age, the sensitiveness of the healthy skin in all individuals is the same.'

Similarly *Carl Beck*, in the *Medical Record* of 1902, asserts: 'The existence of idiosyncrasy has not been proved.'

On the other hand, *Freund* admits the influence of this factor, but does not at the present time give it the importance which he formerly attached to it. He says: 'There is evidence of a sort of idiosyncrasy, each individual reacting to the rays in a special manner.'

Gassmann also asserts: 'One has to take into consideration the idiosyncrasy of certain individuals.' He alludes, however, to certain differences of sensibility in individual cases rather than to a true idiosyncrasy.

Individual Susceptibility.—It seems then finally proved that a true idiosyncrasy does not exist. In two healthy subjects of the same age and sex, the reaction may differ slightly; but if we get only a slight erythema in the one case, we shall not produce a serious dermatitis in the other. Whatever the individual susceptibility, we do not get an ulceration of the scalp from the absorption of a dose of 4 Holzknecht units. Nevertheless, we cannot deny the existence of a certain variation of susceptibility according to age and sex, the part of the body irradiated, the state of the integument, and the effect of previous exposures. All of these factors must be taken into consideration in practice. *Kienböck* has noted these peculiarities, and admits a slight variation in intensity of reaction in different individuals. In most cases children and debilitated persons react more readily. We need not however attach much importance to this point in the practical application of radiotherapy.

We agree with *Holzknecht* that the finer the skin, the more marked the reaction, and hence women are more sensitive in this respect than men.

The question of complexion must also be taken into account. As a general rule, a similar irradiation will set up a deeper erythema on the skin of a blonde than on that of a brunette. On the other

hand, in the case of a brunette the greatest care should be taken or pigmentation may result. In treating a hypertrichosis by epilation, for instance, hyperpigmentation may occur in spite of the greatest precautions, and this without the production of even a partial alopecia. This pigmentation is not permanent however, but disappears after the lapse of some time.

The skin of a child is more sensitive to X-rays than that of an adult, and the adult skin is more sensitive than that of old age. *Scholtz* has also noticed a marked difference in the sensitiveness of the skin in different cases. He agrees with *Freund* in recommending a preliminary séance in order to test the degree of susceptibility. *Carl Beck*, *Holzknecht*, *Gassmann*, and others, are of the same opinion.

This difference of sensibility, however, cannot be called an idiosyncrasy, and need not be taken into consideration unless it is desired to avoid all signs of reaction. In the treatment of an epithelioma the occurrence of erythema or even vesiculation is of little moment, whereas reaction should be studiously avoided in the treatment of hypertrichosis of the face. In women especially, epilation should be produced without any other symptom of reaction. In these cases we should proceed with the greatest caution, and it is advisable to warn the patient of the possibility of accidental reaction and pigmentation.

Regions of the Body.—Not only do different individuals react in a different manner, but in the same individual the sensibility varies greatly, according to the part of the body irradiated.

This fact has been universally recognised. *Holzknecht* says: 'For the same dose the degree of reaction varies for different regions of the integument.'

'Without doubt,' writes *Scholtz*, 'different localities of the body react differently.'

According to the latter, the regions covered with hair, such as the head and cheeks, react most readily to the X-rays. In these situations dermatitis and excoriation often appear somewhat suddenly. He thus explains the etiological significance of these facts: 'Reaction is due to an irritation set up in the deeper layers of the skin by a degenerative process in its cells. The effects of this irritation are added to those of the primary inflammatory process. The tension of the scalp is apt to mask the early inflam-

matory phenomena following an irradiation, and hence the reaction appears suddenly.'

We cannot agree with *Scholtz* that the sensitiveness of a particular region to the X-rays is dependent on the presence of hair. Of all tissues, the scalp is undoubtedly the most resistant to the X-rays. It may be entirely epilated without the occurrence of erythema; occasionally some itching may result, and the skin may become slightly atrophic, but the inflammatory phenomena proceed no further. The same dose produces a much greater reaction on other parts of the body—the cheeks, for example.

The skin of the trunk is rather more sensitive than that of the scalp, and the extensor surfaces react more readily than the flexor. The extremities, the hands and feet, have a high degree of sensibility, and the palmar surfaces are more resistant than the dorsal. In our own experience the thenar and hypothenar eminences seem to have a special sensibility. In two cases of mycosis fungoides treated by X-rays a violent reaction of these regions supervened. There was vivid redness, accompanied by sensations of tension and burning. The epidermis was raised in blisters, leaving the true skin bare, red, and slightly infiltrated. The lesion however healed very quickly. It is interesting to note that on the arm and scalp the same dose produced merely a deep erythematous blush. This was not due to any oversight in the application of the rays, for the same phenomena occurred in the same situation in two different cases. In connection with this increased reaction, we may remember how often severe complications arise as a result of slight injuries to the palm. It will be well in all cases where the palmar surfaces of the hands and feet are concerned to proceed with great caution.

Lastly, the face is very sensitive to the action of X-rays. As is the case with regard to other irritants of the skin, it is the region of the body most readily affected.

The different regions of the face have different degrees of sensibility. The dorsum of the nose reacts more than the alæ, the cheeks, or the lips; the temporal region is less sensitive than the chin. We do not know the meaning of these variations in sensitiveness, nor are they always constant. *Bissérié* is of opinion that the intensity of reaction depends on the proximity of the subjacent bones. Both theory and experience are however opposed to this

hypothesis—viz., that the proximity of the bones can increase the severity of reaction by causing the Roentgen radiations to spread out and be diffused through the substance of the integument.

Fortunately, in practice we need not take much notice of all these variations in sensibility. Radiotherapy is difficult enough without this. With the same dose we may, it is true, get a reaction greater in one region than in another, but the difference is slight. It is well to remember that great precautions should be used in the irradiation of the face, the cosmetic effect depending greatly on the avoidance of all unnecessary reaction.

According to *Schiff* and *Lion*, mucous membranes react more readily than skin. *Lion* irradiated skin and mucous membrane at the same sitting, and observed that the reaction commenced in the mucous membrane. In cases where we have had occasion to treat mucous membrane, such as the lips or buccal cavity, we have not noticed any marked difference between its sensibility and that of the adjacent skin.

Diseased Tissues.—Diseased skin reacts more easily than healthy skin. This is a matter of daily observation, and was first pointed out by *Kienböck*. He says: 'In a region affected by folliculitis or lupus, an acute dermatitis is set up much more readily than in healthy skin.'

Oudin has also noted that integuments which are diseased, inflamed, or ulcerated, are more vulnerable than healthy skin.

Holkznecht says: 'The reaction is the more intense the more the skin is inflamed.'

Scholtz also affirms that skin which has already undergone pathological change reacts more quickly and more intensely to the X-rays. This is true not only in diseases accompanied by intense inflammatory phenomena, such as lupus, acne, sycosis, and folliculitis, but in such diseases as favus, where the difference is most marked. On exposure to the rays the hairs fall out more rapidly from the areas which have been attacked by the disease; and after the irradiation a number of new foci become visible, in consequence of a localized alopecia confined to the diseased spots. Microscopic examination proves that the hairs which are first shed are all affected by the disease.

Scholtz also remarks that in cases of acne rosacea a sharp reaction usually follows an exposure. Our own observations are in accordance with this view.

In a case of lupus erythematosus under our care a violent erythema was set up by the rays. This was arrested exactly at the boundary of the diseased patch, although we had purposely irradiated a margin of skin some 7 or 8 millimetres beyond the affected area. It may be objected that the radiations may have been less intense at the edges of the irradiated area. To this we reply that we were careful to maintain a uniform intensity of irradiation over the whole area. Moreover, as a result of inequal irradiation we should expect to find an erythema decreasing progressively from the centre to the circumference, and not one bounded by a sharp line of demarcation.

Take the case of an ulcerating epithelioma of the nasal region. We may give 9 or 10 Holzknecht units with perfect safety. The reaction may be somewhat severe ; there will be a certain amount of serous or purulent exudation, and there may be some redness at the edges, but that is all. If a similar dose be given in a case of lupus erythematosus of the same region, the reaction will be much more intense. The skin will desquamate, be raised in phlyctenulæ, or even partially destroyed. This is not a question of personal idiosyncrasy, but of a difference of reaction due to the morbid condition of the skin. It is generally allowed by pathologists that a diseased tissue when inflamed does not react to irritant application in the same manner as a healthy skin.

As regards the result, if the dose be not excessive, the increased reaction is not always an unfavourable occurrence. The symptoms of reaction rapidly subside, the skin regains its normal aspect, and often the severe irritation seems to facilitate recovery.

In cases where a considerable dose of the X-rays is indicated, either from the nature of the disease or the course of its evolution, we must carefully watch the nature and degree of infiltration, or we may get unlooked-for results.

Ulcerated surfaces are less easily irritated than those covered by healthy integument. A recent ulcer, for example, will absorb an irradiation of 9 H. without any visible reaction, whereas the adjoining skin will show a well-marked dermatitis.

The X-rays appear to have a special selective affinity for certain morbid tissues, independent of their position or of any inflammatory reaction. This selective action on morbid tissue may proceed without any signs of irritation, or any apparent modification of the skin. Thus the Roentgen rays will destroy cancerous cells

without influencing the healthy tissue in their neighbourhood. Researches by *Pusey* also demonstrate that the irradiation of a neoplasm may determine a modification of its cancerous elements, without any visible effect on the surrounding healthy tissues.

Cumulative Action of the X-Rays.—An important point which has been much discussed is the possible cumulative action of the Roentgen rays. It is well known that certain drugs have a tendency to accumulate in the system, and that in this way minute doses, frequently repeated, may produce serious results.

Does the human organism act in a similar manner with regard to the X-rays? A patient may absorb an enormous quantity of Roentgen radiations without the smallest influence on his general health, provided always that the irradiation is distributed over a considerable surface of the body, and that no region receives more than a certain definite quantity of the rays. If, for instance, he has received on the surface of the trunk a dose of 400 or 500 H. without injury, there is no danger that a subsequent irradiation of 5 H. or 6 H. on the arm will set up a violent dermatitis. In this case the patient will have absorbed an enormous quantity of X-rays without developing any increased sensibility of those regions which have not been irradiated.

This is not the case with tissues which have been repeatedly irradiated. On these the cumulative action is marked. Thus an irradiation of 4 H. on the arm will set up a very slight reaction. If now we give a second and a third exposure at intervals of four or five days, a dermatitis will supervene after the usual period of latency. This occurs in spite of the fact that no single dose of 4 H. is capable of producing dermatitis. There must therefore have been a cumulative action. The results of the X-rays are like those of a drug which is not eliminated from its point of application until after the lapse of a certain interval. It is the length of this time that we must ascertain in order to fix the proper interval between successive irradiations.

Even when there has been a considerable interval between successive exposure, the skin still seems to retain an increased degree of sensibility, and is more easily influenced by X-rays than skin which has not been previously irradiated. This increased sensitiveness often remains after all signs of reaction have long disappeared.

An example may perhaps explain this better. In a case of

epithelioma we gave an irradiation of 8 H. to 10 H. on two consecutive occasions, which was followed by slight reaction and pigmentation. After an interval of three weeks a second dose was given, and was followed by a similar reaction. A third irradiation of less intensity had the same result. Six weeks afterwards there was no trace of any inflammatory action, a few epithelial nodules only remaining. At this juncture a fourth dose was given of the same intensity as the first—*i.e.*, 8 H. or 9 H. A violent reaction followed: the skin became of a deep violet colour, and vesiculation ensued.

In another case of cancer of the breast, with comparatively healthy skin, the same phenomena occurred. At the commencement of the case a dose of 10 H. was given, which was followed by violent reaction and desquamation, but without vesiculation. Two months later, when the lesion had completely healed, a dose of 5 H. was sufficient to produce an intense erythema.

These cases prove that the integument which has been exposed to the influence of the X-rays acquires a special sensibility, or rather becomes less resistant to the action of the rays.

The cause of these phenomena must probably be sought in the degenerative action of the X-rays on the tissues, rendering them less resistant to all irritative agents.

We may therefore absolutely deny the possibility of *Lassueur's* explanation, that the tissues become accustomed to the X-rays, and that this accounts for certain cases of failure in radiotherapeutic treatment.

When it is necessary to submit a case to a series of intense exposures, it is well to diminish the length of the séances after a time in order to avoid dermatitis. The shorter final exposures will often cause greater reaction than did the initial ones of longer duration. This observation confirms what we have already said as to the cumulative action of the rays.

In the treatment of hypertrichosis *Schiff* and *Freund* commence by producing total depilation by a suitable dose of the rays. Afterwards they are able to maintain a permanent epilation by giving one or two séances at intervals of two or three months, which are sufficient to prevent the regrowth of the hair and to cause the shedding of any new hairs which may have appeared.

In conclusion, we may say that, whilst the reaction of the tissues is in proportion to the quantity of X-rays absorbed, other factors

must be taken into account, viz., the sex of the patient, the age, the condition of the skin, the part of the body to be irradiated, any inflammatory conditions, the nature of the lesion, and a difference of sensibility in different individuals.

2. *Factors Dependent on the X-Rays.*

Besides the biological factors which are dependent on the patient, his constitution, and the nature of the lesion, there are others of a purely physical nature which are dependent on the properties of the rays themselves, or on the method of their production. Thanks to our modern instruments of exact measurement, these physical factors can now be accurately estimated.

We have already described the apparatus by means of which these measurements are made, and we need not do so again. We may confine our attention to the study of the properties of the Roentgen radiations without concerning ourselves with the instruments which record them.

Ever since the first application of radiotherapy, experimenters have endeavoured to give technical details which would permit of the comparison of different methods of procedure. Very scanty data were then available, and the information recorded was variable in character and often of only fictitious value. Thus in the earlier observations the only detail recorded is the duration of the exposure. 'The séance lasted for ten minutes' or 'for twenty minutes.' The next step was to record the distance of the skin from the focus-tube. Some months later the type of electric generator was described, and when more precise indications were attempted, the voltage and ampèrage of the primary, the number of interruptions, the length of spark, the size of the focus-tube, and the coloration of the anticathode were recorded. *Kienböck* was the first to distinguish between 'hard' and 'soft' tubes, and thus open the way to further progress.

It is a very regrettable fact that even at the present day the greater number of observations published, both in France and elsewhere, do not contain sufficiently accurate data. Yet we have now had instruments of measurement at our disposal for some time past. *Béclère* has often described them, and *Huguier* made them the subject of an inaugural thesis.

On this matter we may quote *Tuffier*, surgeon to the Beaujon

Hospital: 'As a rule, authors are satisfied to give some vague information, such as the number of times that the patient was irradiated, without stating the degree of hardness of the rays employed or attempting to estimate the quantity absorbed by the patient before the result recorded was attained. All these data are however of supreme importance, and vary enormously with the type of apparatus employed and the way in which it is utilized.'

In November, 1903, together with *Brocq* and *Bisserié*, we exhibited several cases at the Société de Dermatologie, and we then gave precise data of the treatment. Since that date *Haret*, *Desfosses*, and *Tuffier*, when publishing a successful cure of an epithelioma of the nose, gave complete technical details of the treatment in a clear and methodical manner. Recently *Sabouraud*, *Béclère*, *Leredde*, and one or two others have greatly increased the interest of their reports, by giving full numerical data. Unfortunately, their example has not been universally followed.

We daily read notes of experiments, both at home and abroad, where voltage, ampérage, distance from the tube, and time of exposure are all noted, but no record is made either of the quality of the rays employed or of the quantity of radiation absorbed.

In American periodicals where marvellous cures by radiography are frequently reported, we have never yet seen the quantity of radiation recorded. *Morton*, *Pusey*, *Reinhart*, and others, state whether the tubes were hard or soft, the duration of the séance and the distance of the tube from the skin, but these data are not sufficient to determine the quantity of rays absorbed, which is the most important factor in determining the result.

The important factors in radiotherapy are evidently identical with those which obtain in phototherapy.

The Roentgen radiations, or as the Germans say, the Roentgen light, is practically invisible to the human eye. It is, nevertheless, in many respects comparable with the rays of light emitted by the sun and other luminous bodies.

Whatever the luminous source, there are two main points to be considered: the quantity and the quality of the light emitted. The means by which the light is produced is of but secondary importance.

With an ordinary oil lamp the important point is the illumination obtained, not the quantity of oil burnt. We may say that the illumination is proportional to the consumption of fuel; but

this ratio is variable, and depends on many other factors—the type of lamp employed, the total output, and the condition of the lamp; the formula only holds good so long as all these remain unchanged.

In radiotherapy, also, *the important point is the quality of the rays emitted, and the quantity absorbed by the skin.* The voltage and ampèrage, number of interruptions, etc., are merely accessory facts. These may be useful for a given machine, since whilst they remain constant the output will not vary; but they must not be regarded as data of primary importance.

Quality.—*Newton* discovered that the light of the sun is composed of different colours, which may be separated by means of a prism, thus proving that in white light there are an infinite number of radiations of different degrees of refrangibility.

A given light may be either a simple light—red, yellow, green, blue, or violet—or it may be compounded of a number of these simple radiations. When it contains beams of all the simple colours the light appears white.

The radiations from a focus-tube are no less complex. Just as sunbeams differ in refrangibility, so the Roentgen rays differ in their power of penetration. They vary from the softest rays, which are arrested by the dermis, to those of the greatest penetration power, which pass through a plate of iron several millimetres thick.

The quality of the rays given off by a focus-tube is quite independent of their quantity, the two factors having no definite relation to one another, although they may often vary simultaneously.

An increase in the current passing through a focus-tube will affect the quality of the rays, causing them to become harder, while at the same time the quantity given out will likewise increase.

The above fact may be easily demonstrated if we are using Gaiffe's transformer and milliampèremeter.

Supposing with a pressure of 50 volts in the primary, we get a current of 2 milliampères through the focus-tube, and that under these conditions the penetration of the X-rays corresponds to No. 5 on Benoist's scale. If we increase the pressure in the primary to 60 volts, the focus-tube will become more brilliant, and the current through the tube will increase to 3 milliampères. The

penetration of the rays has also increased to No. 8. Not only has there been a change in quality, there is also an increase in quantity. This may be proved by reducing the vacuum by means of the osmo-regulator until the tube gives off No. 5 rays once more. We shall then find the current through the tube is 2·5 milliampères in lieu of the 2 milliampères of the original experiment. The change in quality in the rays has, therefore, been accompanied by a corresponding change in quantity.

This enables us to explain an apparent contradiction. It was found that in certain cases the longer the equivalent spark and the harder the tube, the shorter was the exposure necessary to obtain a given result. Hence the conclusion was drawn that the very penetrating rays were the most active.

This is, we believe, a false interpretation. In increasing the equivalent spark and the hardness of the tube, the principal change is one of quality, but the accompanying increase of quantity more than compensates for the lesser activity of the harder rays.

This may be better understood when a static machine is used as the source of the high-tension current. In a static machine the output increases with the increase of the resistance to be overcome. Hence, as the focus-tube grows harder the current passing through it will also increase, and the quantity of rays emitted will be greater. There will also be a change in the quality of the rays. The maximum penetration registered by the radiochromometer will be higher, but in all probability the tube will be giving out at the same time a number of softer rays in greater abundance.

We know that when a focus-tube is said to be emitting rays of penetration No. 10 of Benoist's scale, what we are really getting is a series of radiations of all degrees of hardness from 1 to 10.

Analogous phenomena may be observed in the domain of physics. If we take a platinum wire and connect it to the terminals of an electric battery, when the current passes the wire will be heated. If we increase the strength of the current, the wire will become dull red, cherry red, and finally white hot and luminous.

No one imagines that when the wire emits light rays it has ceased to give off heat, or that the emission of other forms of radiation is arrested when it becomes incandescent. This phenomenon is strictly analogous to that which occurs in the focus-tube.

With the same vacuum then, the tube becomes harder as the current through it increases; that is to say, the number of the

rays is increased, and some of these are of a more penetrating quality.

The increase in quantity takes place along the whole gamut of rays of various degrees of penetration, probably however, only within certain limits.

Hence, on account of the increase in quantity, it is quite possible that a tube emitting No. 10 rays may be more active therapeutically than one giving No. 5 rays. We cannot however admit that a 'very hard' tube, which only emits a small number of very penetrating radiations, can possibly be as efficacious as a 'soft tube' giving an abundance of rays of medium penetration.

These phenomena may more readily be understood when the focus-tube is driven by a static machine. From the principles of construction of an influence machine, we know that the output increases automatically with the resistance opposed to the current, the energy required to drive a static machine increasing in proportion to the work demanded of it.

This is not the case with an induction-coil, which has a fixed maximum output, which cannot be exceeded. If the resistance becomes too great, the current will not pass at all, unless the voltage of the primary is raised. This can only be done within certain narrow limits, which are determined by the construction of the instrument.

With an induction-coil therefore, any increase in resistance above a certain optimum value causes a decrease in the current, and a consequent decrease in the quantity of rays emitted, since the electric energy in the secondary circuit has a fixed maximum value, which cannot be surpassed as long as the voltage and ampèrage in the primary remain constant.

This will explain why *Sabouraud*, using a static machine, obtained an epilation more readily with rays of No. 10 of Benoist's scale than with No. 4 or No. 5.

He remarks: 'The greater the penetration of the rays, the greater is the total quantity produced; the penetration seems to be practically proportional to the quantity emitted.'

As we have shown above, this relation holds good only under certain conditions, and with a special type of instrument.

The quality of the rays emitted by a focus-tube depends on the difference of potential between its electrodes.

This difference of potential varies according to the power of the

source of electrical energy, whether static machine or induction-coil, but it depends chiefly on two main factors:

1. The vacuum within the tube.
2. The resistance of the circuit in which the tube is interpolated.

The penetration of the rays will increase or decrease with the vacuum in the focus-tube, and also with the resistance of the secondary circuit. During use a Crookes tube gradually gives out rays of a more and more penetrating character. It may be 'softened' by simply warming the glass, and thus liberating the occluding gas, or it may be more easily adjusted by means of a regulator attached to the tube.

In order to vary the resistance of the secondary circuit, we may interpose a spark with two terminal knobs, one of which is adjustable by means of an insulated handle.

In radiotherapeutic practice it is better to keep the external resistance constant, and to regulate the quality of the rays by altering the vacuum in the focus-tube. In this manner we are able to maintain the greatest constancy of irradiation.

The higher the vacuum, the greater the penetration of the rays; whereas a low vacuum gives radiations of feeble penetrative power. In the former case the tube is said to be 'hard,' in the second 'soft.'

In a communication to the Immelmann Institute at Berlin in 1900, *Dr. Strätter* first drew attention to this subject. He showed that the different radiations from a focus-tube exhibit the greatest variations in their properties.

Some traverse the body without absorption or any appreciable transformation of their energy into chemical action in the tissues, while others which have less power of penetration are readily absorbed by the skin, and consequently react more energetically.

Kienböck, however, was the first to study this question scientifically. He divides focus-tubes into five categories, according to their vacuum and the quality of the rays which they emit.

In the first class he places 'extra hard' tubes. These have a vacuum too high to permit the passage of a current even from a powerful coil. They do not yield X-rays, but give off electric effleuves, the current passing round the outside of the tube.

To the second class belong the ordinary 'hard' tubes. A current of high tension can pass through these tubes, a portion being converted into Roentgen rays of a high degree of penetration. They

give an image on the fluorescent screen or photographic plate, but the shadows are wanting in contrast. The bones are almost as transparent as the softer tissues to these very hard rays, which are only absorbed in a slight degree by the tissues.

The 'medium hard' tube, the most useful of all, is placed in the third category. The vacuum is much lower, and the greater portion of the current traversing the tube is converted into X-rays. It therefore gives a strong illumination with rays of medium penetration. It gives a highly-contrasted image on the screen.

These rays are much more readily absorbed than the more penetrating radiations of a hard tube, and therefore react more powerfully on the tissues, more particularly the skin, which is the first to encounter the impact of the rays.

On the deeper tissues their action is less marked, since the rays have been much enfeebled before reaching them, and there is but little energy remaining to be transformed into chemical action.

In the fourth class *Kienböck* places 'soft' tubes. In these the vacuum is low, the illumination is very bright, and the whole of the current is converted into X-rays. The tube may be handled without fear of a shock. The X-rays produced have but little power of penetration, and can only pass through the thinner parts of the body. When the hand is examined with such rays, the bones appear black on the fluorescent screen, since they cut off all the radiations. These rays are almost entirely absorbed by the superficial layers of the skin, a small portion only reaching the subdermal tissues.

In the last category are the 'extra soft' tubes. These have too low a vacuum to yield X-rays. They are therefore as useless as the ultra hard tubes for radiotherapeutic purposes.

As a practical means of estimating the quality of the rays issuing from a given tube, *Kienböck* mentions the appearance of the glow from the tube, the pitch of the sound made by the break, the effleuves from the tube, and various other signs, all of which are variable and difficult to interpret correctly.

Thanks to Benoist's radiochromometer, we have now an accurate instrument which is capable of indicating at any moment the precise quality of the rays issuing from a focus-tube.

This instrument has already been described in an earlier chapter. By its aid we can distinguish twelve or more different types of

radiation, from the slightly penetrating No. 1 to the very hard No. 12 rays. *Béclère* holds that by means of this instrument we can determine the quality of the rays employed just as readily as we can tell the time from the hands of a watch.

It is not however enough to be able to measure the quality of the rays which we are obtaining; we should also be able to produce at will whatever type of rays we may require.

The penetration of the rays depends on the vacuum in the tube. Further, a tube which originally gave soft rays will gradually grow harder, and after even a few minutes' use the rays will have become much more penetrating; whereas during a radiotherapeutic exposure we require rays of a definite and constant degree of penetration.

To obtain this result we make use of regulating focus-tubes—*i.e.*, tubes which have a device for altering the vacuum. The best of these, and in our opinion the only one suitable for therapeutic work, is the Chabaud tube with Villard's osmo-regulator.

In practice it has been found impossible to keep a continual watch on the radiochromometer, so as to be ready to heat the osmo-regulator when the rays become too hard. An ingenious method has been devised to obviate this. A spark-gap is introduced into the secondary circuit in parallel with the focus-tube. The distance between the adjustable knobs of this spintermeter, as the instrument is called, can be easily read off on a graduated scale.

By means of the radiochromometer and the osmo-regulator the vacuum in the focus-tube is altered until the desired quality of rays is obtained. When this has been accomplished the knobs of the spintermeter are approximated until a spark passes between them. At this moment no current passes through the focus-tube, and it becomes dark. The knobs are now slowly separated until the sparks cease to pass. The distance between them is then read off on the graduated scale, and the quality of the rays issuing from the focus-tube is verified. As soon as the resistance in the tube increases, the current will spark across the gap in the spintermeter. This will warn us of a change in the quality of the rays. We then warm the osmo-regulator until the sparks cease to pass between the knobs of the spintermeter, and we then know that we are getting rays of the same quality as before. The distance between the spintermeter knobs is termed the length of

the 'equivalent spark,' and should always be noted as one of the data of an exposure.

For a given installation and a given focus-tube, where the voltage, ampèrage, and frequency of interruption are kept constant, the same spark-gap will always correspond to the same quality of rays.

A table may be drawn up, giving the length of spark corresponding to rays of every degree of penetration ; and once this is done, we need only adjust the spintermeter, and by a suitable regulation of the vacuum in the tube, we may obtain rays of any desired quality. It is not possible, however, by this means to compare X-rays from different installations. The length of the equivalent spark depends on the size of the spintermeter balls, the power of the generator, and the type of focus-tube employed.

Messrs. Gaiffe have recently designed a very sensitive milliampèremeter, which measures the current actually passing through the focus-tube. If the electrical conditions in the primary circuit are kept constant, any variation in the secondary current must be due to a change in the resistance of the tube caused by an alteration of the vacuum. Thus, any movement in the index of the milliampèremeter will indicate a change in the quality of the rays emitted by the focus-tube. This instrument is much more sensitive than the spintermeter, and indicates variations in the vacuum in either direction, the spintermeter giving only a measure of the maximum resistance.

The measurement which we require for purposes of comparison is that given by the radiochromometer. This is the only instrument which enables us to express numerically the exact quality and quantity of the rays employed.

The length of the equivalent spark and the number of milliampères in the secondary circuit are important data, which should by all means be given where possible; but from a technical point of view, they are only of use in connection with the particular installation employed, and are valueless for purposes of comparison.

We must now consider what quality of rays gives the best results in the treatment of skin diseases. To determine this question correctly we must remember the fundamental principle: 'X-rays react only on tissues which absorb them, and the reaction is proportional to the quantity of rays absorbed.'

Rays of No. 10 or No. 12 on the radiochromometric scale pass

through the skin without absorption, and therefore produce no effect on it.

In a previous chapter we showed that the physiological action of the rays on the skin varied inversely as their power of penetration. Hence, for cutaneous radiotherapy we prefer rays of slight penetrative power. There is, of course, a minimum of penetrability which must not be passed. Rays corresponding to No. 1 or No. 2 on the radiochromometer are only of use in very exceptional cases. Their action is limited to the most superficial layers of the skin, since they will not penetrate the thickness of the dermis.

In dermatological practice we use rays of medium penetration, No. 5 and No. 6 on Benoist's radiochromometer.

It is evident that the penetration of the rays should vary according to whether we wish to affect the skin or the subcutaneous tissues, rays of greater penetration being required in the treatment of deeply-seated affections. This has been recognised by many authorities. *Morton* of New York prefers a hard tube for deep-seated lesions. It seems to us however, that a most important point has been overlooked. The very penetrating rays cannot be therapeutically active because they are not absorbed by the tissues. In this connection *M. Béclère* writes: ' Other things being equal, the less the penetration of the rays, the greater will be the proportion absorbed during their passage through the tissue. It is only the fraction of the radiation arrested and absorbed which causes therapeutic reaction.'

We have thus two facts apparently opposed to one another: X-rays of small penetration have a marked therapeutic action, in consequence of their ready absorption by the tissues. On the other hand, those highly-penetrating rays which are capable of reaching the deeper tissues are apt to pass through them without absorption, and therefore possess but slight therapeutic activity. We know that the power of absorption of a body for the X-rays depends on its density. Now, the density of a deep-seated tumour differs little from that of the skin. Any rays therefore which have passed through the skin without affecting it, can have but little influence on the subjacent neoplasm.

It is, of course, possible that the X-rays may have some selective action on the cells of cancerous growth; but this elective affinity would hardly explain the cure of a cancer of the stomach without any sign of cutaneous reaction. Yet such a case has been

recorded. We would be the first to admit the selective action of the rays, but even if the cancer cells were many times as sensitive as normal tissue, we should still expect to get some visible reaction of the integument.

The important point is to employ rays of such penetration that they will just be able to reach the affected part, and will be in great measure absorbed by it.

For subcutaneous affections this condition is easily realized, but it is a much more difficult matter to treat deep-seated tumours. In this case, many authorities recommend the use of rays of great penetration.

Personally, in such cases—in a cancer of the breast, for instance—we use rays of medium penetration, corresponding to No. 7 of Benoist's scale. These are of sufficient penetration to reach the tumour, and are less injurious to the skin, which is peculiarly sensitive in these cases. The quantity of rays absorbed by the neoplasm is probably not large, but the special sensibility of morbid growth may compensate for this. We must, however, admit that the results we have obtained in these esses have not been very brilliant. In the treatment of skin disease there is no doubt as to the proper tube to be employed. It should be a fairly soft one, giving rays corresponding to about No. 5 on Benoist's scale, with a variation of 1 degree on either side, according to the case.

Quantity.—A source of light, whatever its nature, excites the retina in a greater or less degree. We express this by saying that the intensity of the light is greater or smaller.

Thus an electric lamp may give an illumination of from 20 to 100 candle-power, according to its type and the quantity of current passing through it. A gas-jet turned down gives less light than when it is full on.

In an X-ray tube the phenomena are the same. A given tube gives out in a given time a greater or smaller quantity of X-rays, according to the quantity of electrical energy supplied to it, and this it does whatever its vacuum and the penetration of the issuing rays.

'Imagine,' says *Béclère*, 'two similar focus-tubes, one supplied by a two-plate static machine turned by hand, and the other by a twenty-plate machine driven by a powerful electro-motor. By suitably adjusting their vacuum, it is possible to obtain rays of the same quality—that is, rays of equal penetration from either

tube; but whilst the former will emit but few rays, the latter will give a much larger quantity. They are like two lanterns of the same colour, one of which is lit by a candle and the other by an electric light.'

The exact measurement of the quantity of the rays emitted by a focus-tube is of great importance in radiotherapy, since the degree of reaction depends on the quantity of rays which strike the skin and are absorbed by it.

Until lately an attempt was made to estimate this quantity by stating the wattage in the primary circuit, the number of interruptions per second, the type of coil, etc. These data have no real value, as the quantity of rays depends in great measure on the efficiency of the coil and tube. With the same current in the primary, very different results may be obtained by the use of different kinds of apparatus. Further, it is impossible in all cases to secure the same strength of current in the primary circuit.

An installation worked from the public mains may give four times the quantity of radiation furnished by another apparatus driven by accumulators.

Again, with a static machine, what means have we of estimating the quantity of X-rays issuing from the tube? In order to form any comparison, we should have to measure the induced alternating current in the secondary circuit of the coil and the high-tension continuous current of the Wimshurst. Both these measurements are exceedingly difficult to obtain with the means at our disposal, and their comparison is still more difficult.

Gaiffe's milliampèremeter comes to our assistance by enabling us to measure the current actually passing through the focus-tube. By the use of Gaiffe's transformer, in conjunction with the milliampèremeter and a voltmeter, we can compare two quantities of X-rays, can double the quantity, can increase or decrease it. We are not able however, to measure the absolute value of the rays at their point of application. Two factors have to be considered as regards quantity—viz., the quantity of rays emitted by the tube, and the quantity of rays which actually fall on the surface of the skin.

These two quantities are mutually interdependent, but they are not identical.

A focus-tube gives out a greater or less quantity of radiations according to the power of the installation employed.

This quantity should be measured close to the point of emission —*i.e.*, the anticathode. Its determination is, however, of no practical interest. What we do require is the quantity of rays which reach the skin.

This depends not only on the quantity emitted by the tube, but also on the distance from the anticathode to the skin, and on the duration of the irradiation.

The quantity of radiation falling normally on a given surface varies inversely as the square of its distance from the luminous source. This law applies to X-rays in common with all other ethereal vibrations.

Consider a point on the skin at a distance x from the source of radiation, and let its effect be expressed by y. When the distance is $2x$, the effect will become $\frac{y}{2^2}$ or $\frac{y}{4}$.

In order to measure the quantity of light falling on a given surface, we make use of an instrument called a photometer. *Holzknecht* has devised a similar instrument for measuring the irradiation of a surface by the X-rays. This is the radiochromometer. We have already explained that it is based on the changes in coloration which certain salts undergo when exposed to the X-rays. It is composed of a series of pastilles and a graduated scale for comparison. At the commencement of the treatment we place a capsule, the colour of which corresponds to zero of the scale, on the part to be irradiated. From time to time during the séance we compare this capsule with the graduated scale, and continue the exposure until it has reached the tint which corresponds to the quantity of rays prescribed. By this means we avoid all danger of an overdose.

In practice we may determine once for all the quantity of rays absorbed at a given time at a given distance from the tube. So long as our electrical factors remain constant, we may always be sure of obtaining the same quantity under identical conditions.

The following was our method of procedure with our installation at the Broca Hospital: We first adjusted the voltage and ampèreage of the primary, the frequency of interruption, the quality of the rays, and the length of the equivalent spark. All these factors were kept constant. Then one of Holzknecht's pastilles was placed at a distance of 10 centimetres from the anticathode, so that the incident rays would fall on it normally. After ten minutes' irradia-

tion we compared the pastille with the scale, and noted the number which it matched. This observation was repeated with fifteen, twenty, twenty-five, and thirty minutes' exposure.

We thus constructed a table of quantities in which the only variable factor was the time. By keeping the distance and the electrical condition constant we always obtained the same quantity of rays in a given time.

If we desire to increase the distance, the quantity absorbed can be calculated by applying the law of the inverse square.

At the Broca Hospital we made a second set of observations at a distance of 15 centimetres from the anticathode, and the results obtained agreed fairly well with those calculated theoretically.

We need not give the numerical values obtained, as they only apply to the particular installation and focus-tube for which they were measured. A fresh table of quantities must be constructed whenever a new focus-tube is used.

By this means we can measure a dose of X-rays almost as exactly as a dose of medicine. For example, we find that by exposing the area to be treated at a distance of 10 centimetres for fifteen minutes, it will absorb a dose of 4 H.

The quantity of rays absorbed by a given surface may be altered by varying either the distance or the time of exposure.

Supposing the skin absorbs a dose of 3 H. in ten minutes when it is 10 centimetres from the anticathode: we shall get the same effect at twice the distance—*i.e.*, 20 centimetres—if we multiply the time by the square of 2 and give an exposure of forty minutes.

In the practice of radiotherapy the part to be treated should always be placed as near the tube as possible, the time of exposure being regulated as may be necessary.

'The closer,' says *Oudin*, 'the focus-tube is placed to the patient, the more powerful will be the action of the rays on the skin. It should be placed in such a position that the cone of rays will cover the whole area to be treated, and as close as possible, so long as there is no danger of sparking from the tube to the skin. Under these circumstances the exposure will be of short duration.'

This method would be excellent if the rays issued from the tube and fell on the skin in parallel beams. Since, however, they are emitted from a point, they are unequally distributed over the whole surface of the skin, and this irregularity of irradiation can

only be obviated by a careful study of the laws which govern the intensity of illumination at different points.

The importance of this consideration is obvious, when we reflect that any irregularity in the quantity of radiation will cause variations in the therapeutic effect.

Local Variations in the Intensity of Radiation.—We will now proceed to determine the best arrangements which can be adopted in the practical application of the rays.

The points to be considered are:

1. To obtain an equable distribution over the whole irradiated area.

2. To reduce the duration of the exposure to a minimum.

In order to understand the variations of intensity of the X-rays at different points, we must recall the two fundamental laws which determine the intensity of ordinary light rays:

(*a*) The quantity of light falling normally on a given surface varies inversely as the square of the distance of that surface from the source of light.

(*b*) The quantity of light falling obliquely on any surface varies as the sine of the angle which the incident ray makes with the surface.

These laws have been deduced from geometrical properties common to all radiations, and are therefore independent of the properties of any particular form of radiation. Hence they are applicable to the Roentgen rays as well as to light and heat.

We will first examine the theoretical consequences of these laws, and then proceed to the more practical considerations.

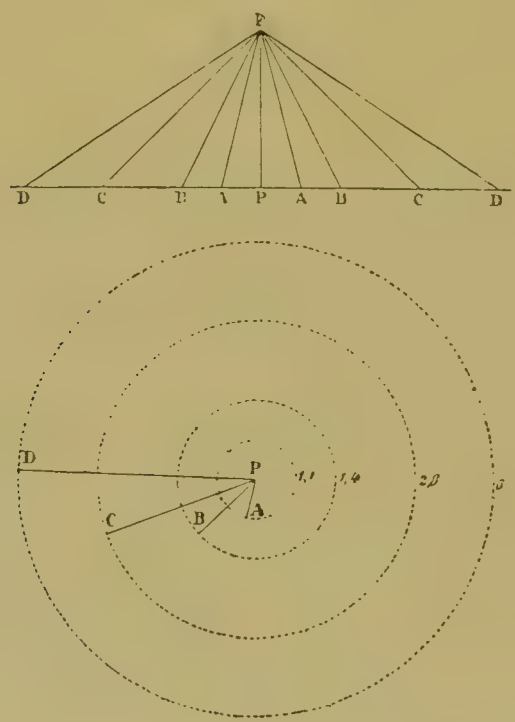
First Law.—The law of the inverse square shows us that in order to reduce the time of exposure to a minimum, we should place the source of radiation as close as possible to the irradiated surface.

Thus if an exposure of five minutes is required when the distance is 3 inches, an exposure four times as long, or twenty minutes, will be needed if the distance is increased to 6 inches, and a time nine times as long, forty-five minutes, would be required if the anti-cathode were removed to a distance of 9 inches, while at a distance of 12 inches the exposure would be nearly an hour and a half.

These numbers are in reality below the true value, for not only does the intensity of the rays diminish with the square of the

distance, but they are still further reduced by dispersion by the molecules of the air which they traverse.

In practice the area to be irradiated is generally of some considerable extent. If we consider a plane surface, it is manifest that the distance from the source of the X-rays to any point on the surface will increase as we pass from the centre to the circumference.



This increase in the distance causes a corresponding decrease in the intensity of the radiation, and the therapeutic effect produced at the periphery will be sensibly less than that at the centre.

Let F be the source of the rays, placed vertically above the centre of a plane surface. Let P be the base of the normal from F, and A, B, C, D points at increasing distances from P.

Let us suppose the surface divided into concentric circles, whose diameters are respectively equal to half of FP, FP, twice FP, thrice FP, etc., FP being the distance from the source to the centre.

The distances from points on these circles are respectively

FA, *FB*, *FC*, *FD*, and the squares of these distances are equal to *FP* square multiplied by

$$\left.\begin{array}{l} 1{\cdot}06 \\ 1{\cdot}25 \\ 2 \\ 3{\cdot}25 \end{array}\right\} (a)$$

This table shows that the intensity of irradiation will be nearly constant over the whole surface, if its greatest diameter is less than its distance from the focus.

When the diameter is equal to the focal distance, the intensity of irradiation at the edges is not more than three-quarters of that at the centre.

In order to obtain the same results at the edges as at the centre, the former would have to be irradiated for one-third as long again as the latter.

When the greatest diameter of the surface is two or three times its distance from the source, the intensity at the edges is only one-half to one-third of that at the centre. To obtain an equable reaction we should therefore have to irradiate the edges for a period two and three times as long as we give at the centre.

Second Law.—The law of sines explains a further difficulty in obtaining an equable effect on all points of an irradiated surface. The preceding figure shows how the inclination of the rays increases with the distance of the point of incidence from the centre.

The sines of the angles between the incident rays and the surface will therefore decrease as we pass from the centre to the circumference. This decrease is however small for fairly large angles. In the figure the angles are :

$$\begin{array}{l} 76^\circ \\ 64^\circ \\ 45^\circ \\ 33^\circ \end{array}$$

and the corresponding sines are :

$$\left.\begin{array}{l} 0{\cdot}97 \\ 0{\cdot}90 \\ 0{\cdot}71 \\ 0{\cdot}54 \end{array}\right\} (b)$$

Therefore in order to obtain the true value of the intensity at the boundaries of the surfaces which we have been considering, we must divide each number in column (*a*) by the corresponding number in (*b*).

The results will be:

$$\left.\begin{array}{l} 1{\cdot}1 \\ 1{\cdot}4 \\ 2{\cdot}8 \\ 6 \end{array}\right\} (c)$$

Hence to obtain an equable irradiation over the whole surface its greatest diameter must not exceed one-half of the distance of the surface from the source.

To obtain an equable irradiation of a surface whose diameter is equal to its focal distance, the length of exposure for the periphery must exceed that for the centre by more than 40 per cent. For areas whose breadth is twice or three times the distance from the source, the exposure required will be respectively three and six times as long at the periphery as at the centre.

Thus the correct distance of the focus-tube from the patient is fixed by the size of the surface to be treated. The distance must always exceed twice the greatest diameter of the area to be treated, if an equable therapeutic effect is to be produced at all points on the surface.

In certain cases this would necessitate so great a distance that the time of exposure would be unduly prolonged. We may then consider the advisability of reducing the distance, and shielding the central portion of the surface after a time, whilst continuing the irradiation of the periphery.

The numbers given above (*c*) will serve as a guide to the relative length of exposure required.

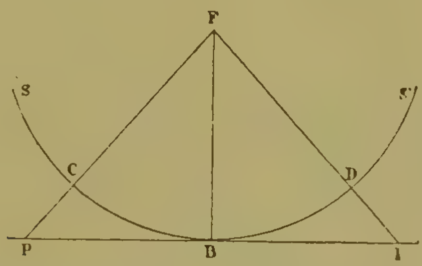
This solution of the difficulty is not very satisfactory. In practice it is generally found better to divide up a large surface into smaller areas, and to treat one of these at a time, whilst protecting the others by means of a lead shield.

The figures we have given above are only approximately correct in practice, since they are only true for an absolutely plane area, whereas the surfaces we are called on to treat are always more or less convex or concave.

For concave surfaces distances from the source will diminish less rapidly than for a plane surface, and may even be equal if the

surface is the segment of a sphere of which the anticathode is the centre. In this case the angles of incidence would also be equal.

Thus for a surface whose general contour is concave the distance from the focus to the surface may be much less than half the greatest diameter.

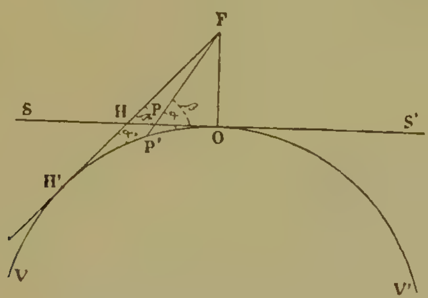


On the concave surface SS′

$$FB = FC = FD < FP \text{ or } FI.$$

On the other hand, when the general form is convex, the distance from the source to the points further recovered from the centre will increase more rapidly, and the inclination of the rays to the skin will be more acute than when we are dealing with a plane surface.

If the convexity is very pronounced, the area treated at a sitting should be restricted, and the surface divided into several smaller portions, each of which must be irradiated in turn. In this way we eliminate the oblique rays which fall almost tangentially on



the outer edges of such a convex surface, and are therefore therapeutically inactive.

Let SS′ be a plane surface, VV′ a convex surface, and F the source of radiation. The distance FO from the source to the nearest point of the surface is the same whether the surface be plane or curved. For all other points the distances differ.

Thus:

$$FP < FP'.$$
$$FH < FH'.$$

The ray FHH′ is tangential to the surface V, and its action is therefore practically nil.

Again:

$$\text{Sin } \beta > \sin \beta'.$$

Also:

$$\text{Sin } \beta > \sin a. \qquad \text{Sin } \beta' > \sin a'.$$

And

$$\text{Sin } a > \sin a'.$$

To conclude: in radiotherapeutic treatment we endeavour to reduce the distance as much as possible, but we must also endeavour to avoid the use of very oblique rays.

We may give the following as the formal rule:

The source of the X-rays should be placed at a distance at least double the greatest diameter of the surface to be irradiated.

In practice the distance from the anticathode to the skin may be adjusted automatically. By the use of suitable conical anticathodes we may limit the cone of rays so that it is impossible to illuminate the whole of the area unless the tube is placed at the proper distance. It is only necessary for this purpose to calculate the correct aperture of the conical anticathode.

Another method is to make the focus-tubes of a special glass impermeable to the rays, and to furnish it with a transparent window whose diameter is equal to one-half of its distance from the anticathode. These tubes are, however, very expensive and difficult to make.

At the Broca Hospital we employ a simpler method to insure uniformity of irradiation. The focus-tube is enclosed in a protective case, which is impermeable to the X-rays. In this box, opposite the anticathode, is a circular aperture the diameter of which is equal to one-half of its distance from the latter. The position of this opening is such that its axis coincides with the normal incident ray from the anticathode. This aperture forms a sort of diaphragm the distance of which from the skin determines the size of the irradiated area. In this way we can readily insure a uniform irradiation, and consequently an equable therapeutic effect over the surface.

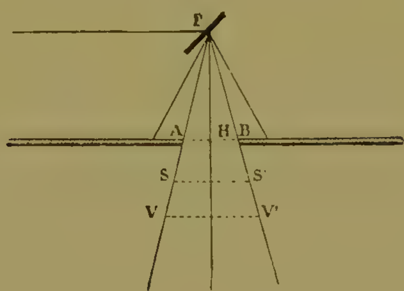
This arrangement has been somewhat elaborated in Gaiffe's localizer. The accompanying figure may make the device clearer.

Let F be the point of emission of the rays, and AB the diaphragm or aperture in the box:

$$AB = \frac{FH}{2}.$$

The irradiation of the surface SS′ will be uniform. If it is desired to irradiate a larger area the tube must be placed at greater distance from the skin, so that the cone of rays may include a larger area VV′. In this case the time of exposure will be correspondingly increased, and may be calculated by the law of inverse squares.

Kienböck first noticed this unequal irradiation, and studied it experimentally. He observed different zones of reaction, varying



from ulceration at the centre in close proximity to the tube, to simple alopecia at the periphery where the irradiation had been less intense.

Holzknecht, in his work on the treatment of alopecia areata, makes a similar observation. 'The focus-tube,' he says, 'should be placed as close as is compatible with the equable irradiation of the skin; the distance of the tube should therefore increase with the area of the surface to be treated, and also with its convexity.' This theory is in accordance with experience, and the law given above is found to be of practical utility.

In treating a given case we find that as far as regards the horizontal planes, those which are raised are more affected than those which are depressed; whereas the action on curved and receding surfaces is much less marked.

In the case of a young female patient of dark complexion, suffer-

ing from hypertrichosis, we exposed the back of the hand to a slight irradiation of about 4 H. In the course of seven or eight days a general pigmentation of the whole of the irradiated surface followed. On the back of the hand, and on the middle of the back of each finger, the coloration was intense. On the curved portions between the back and sides of the fingers the skin retained its normal appearance. The lateral surfaces of the fingers were also unaffected, although the fingers had been slightly separated during irradiation.

On the plane surfaces the rays had fallen perpendicularly, whereas they were almost tangential to the curved margins of the fingers, producing a great effect in the former case and none in the latter. In treating a lesion of the nose, if the cone of rays is directed on the dorsum, it is found that the reaction is greatest on the bridge of the nose and the roots of the alæ nasi, whereas it is less marked on the junction of the body of the organ with the alæ. We may get a more uniform action by treating each side separately. The tube should be placed so that the normal incident ray falls vertically on the lateral face, which is more or less concave. It is however, on the scalp that we can best study results of unequal irradiation. In the treatment of tinea by epilation it is usual to attack as large a surface as possible. We have seen cases where the whole of the upper portion of the scalp has been treated by one exposure, the field of action being limited only by the convexity of its boundaries. The results were as follows: The hair first fell out from the centre, and later on from the periphery; at the edges the epilation was incomplete. In order to obtain this incomplete epilation of the periphery an excessive dose had been given. The skin which had been irradiated by the centre of the cone of rays was atrophied, and the hair had not begun to reappear, whilst it was growing thickly elsewhere. If the radiation had been equable over the whole surface, the reaction would have been equally marked at all points, and the growth of hair would have been simultaneous throughout.

In treating lesions of great extent, such as mycosis fungoides, one might be tempted to place the tube close to the surface and treat as large an area as possible. The result would be disastrous. In the centre there would be ulceration, at the edges a barely perceptible erythema, and the disease would not be cured. In such a case the area to be treated must be strictly limited, so as to insure

uniformity of irradiation, so that an equal quantity of rays may be absorbed by each portion of the skin.

It may be objected that these considerations are of only theoretical value. In a radiotherapeutic exposure we nearly always have to encroach slightly on the healthy skin surrounding the lesion, and it might therefore be thought an advantage that the action at the periphery is less intense. This objection would be valid if this apparently healthy tissue were really unaffected. But if, as is probable, the morbid growth has extended beyond the limits of the visible region, its destruction will require a larger dose of the X-rays, since comparatively healthy tissue reacts less readily than diseased tissues.

What quantity of X-rays should be absorbed in order to obtain the best therapeutic results, is a question to which it is impossible to give a categorical answer.

It is not difficult to prescribe the approximate dose necessary to cure a given affection, so long as this quantity is less than that which will produce radiodermatitis. In such a case the question is simple. The entire dose is given at one sitting, as *Sabouraud* does in the treatment of tinea. There is no serious reaction, and the cure generally results from a single exposure. In the case of tinea the dose varies but little, for the scalp is usually the part affected, and on account of its slight sensibility there is little variation in different individuals. But in other cases the question is much more complicated. As *Béclère* says: 'In the treatment of many affections amenable to radiotherapy, the problem of dosage is a most difficult and complex one. This is especially the case in the treatment of cutaneous or subcutaneous neoplasms, since we must take into account the diversity of lesions, the differences in age of the patients, the topography of the region affected, the histological structure, the area, and still more the depth of the diseased structures, the clinical evolution, and the possibility of transference by means of the lymphatics and bloodvessels.

Usually the total dose necessary to effect a cure exceeds that which can be safely given at a single sitting without the production of dermatitis and ulceration. Radiodermatitis is not necessary for a cure; it is most often an accidental complication, sometimes a foreseen result, but very seldom a desired effect.

Where a single dose is dangerous, we must give a series of exposures, and thus divide the dose. *Béclère* most aptly compares the

action of X-rays to that of mercury. In the use of this drug we cause the patient to absorb the largest dose compatible with the integrity of his organic functions. 'In the treatment of syphilis by means of insoluble salts,' he writes, 'we give at each injection the maximum dose compatible with the integrity of the buccal mucous membrane, and we diminish the intervals between the injections as much as possible, with due regard to the state of the mouth. The dose will vary according to the temperament of the patient—his age, his physical condition, the form and stage of the disease.' In treatment by the X-rays the problem is the same.

We desire to obtain the absorption of the quantity necessary to effect a cure as quickly as possible. As this quantity generally exceeds the normal dose, we separate the séances, and give at each exposure the dose necessary to provoke the required degree of reaction, whilst preserving the integrity of the skin. The time between each irradiation we make as short as is compatible with this requirement.

These rules are not absolute, and must be modified to suit individual cases. In some cases it is advisable to give less than the maximum dose, since better results are obtained by shorter exposures at more frequent intervals.

Holzknecht has fixed the maximum dose which the healthy skin can absorb without danger to its integrity, and at the same time has given us a most valuable means of measuring its quantity. The following are his indications:

For young subjects a dose of 3 H., and for adults a dose of 4 H., is required in order to produce reaction of the first degree—*i.e.*, epilation without redness in the healthy skin of the face.

A dose of 5 H. to 7 H. is required in order to set up a reaction of the second degree—*i.e.*, a superficial erosion without ulceration, followed by healing without scarring.

On the surfaces of flexure of the joints a dose of 4 H. to 6 H. will produce reaction of the first degree, and a dose of 6 H. to 8 H. will produce reaction of the second degree.

For the surfaces of extension of the joints, the trunk, the scalp, the palms of the hands, and soles of the feet, a dose of 5 H. to 7 H. will produce reaction of the first degree, whereas 7 H. to 14 H. will be required to produce reaction of the second degree.

A certain deduction must be made from these doses in the case of skin which is the seat of inflammatory changes, either from

disease or from radiodermatitis. This deduction should be 1 H. or 2 H. for a dose of 6 H., and 2 H. or 3 H. where more than 6 H. would be required for the normal skin.

For plate cultures of bacteria 20 H. is the average amount which should be given at each exposure.

In the present state of our knowledge the maximum dose may be fixed at 10 H. per month. This quantity must not be exceeded, except after due consideration, and with the certainty of producing an ulceration lasting many weeks.

These data, as *Holzknecht* himself points out, require confirmation and amplification by further experiments, since the subject is too extensive for a single investigator.

The above doses are supposed to be given at a single sitting.

Those who prefer fractional doses may divide the total quantity into eight or ten consecutive exposures at intervals of two or three days. In this case the total amount should be slightly increased, for the tissues have time partially to recuperate after each exposure. A totally different effect is obtained when a quantity of 10 H. is given at a single sitting, and when it is divided into ten exposures, with two days' interval between each sitting.

At the Broca Hospital we give the required dose in a single séance, or on two consecutive days, according to the requirements of the case.

The following are the quantities which experience has led us to adopt: We give 4 H. or 5 H. in one or two exposures in order to produce epilation of the scalp in the case of tinea. For the face we do not exceed 3 H. or 4 H. We then await the result and increase the dose if necessary.

A dose of 4 H. to 6 H. may be given in cases where we desire to secure a superficial effect on a comparatively healthy tissue, as in pruritus, hypertrichosis, etc.

When a stronger action is desired, and when the tissues are but little inflamed, we may increase this dose.

We use 5 H. to 6 H. in the treatment of the seborrhœides, eczema, acne, etc.; 4 H. to 5 H. is sufficient for psoriasis.

With 8 H. or 9 H. in cases of lupus erythematosus, we get a very strong reaction which heals with difficulty, and only after the lapse of a considerable time. The same may be said of lupus vulgaris. The dose of 4 H. should not be exceeded in cases where reaction is to be avoided. The maximum dose is 8 H. or 9 H., which is usually followed by ulceration of more or less intensity.

Seven H. or 8 H. may be given in cases of cutaneous epithelioma. In these cases the reaction is sometimes very intense, but it is rarely followed by serious consequences, and the tumour usually undergoes rapid change. If the lesion is ulcerated, this dose may even be exceeded without inconvenience, but care must be taken to protect the neighbouring healthy skin by means of a lead shield.

In cases of recurrence after operation, and in malignant tumours of the breast, with or without glandular enlargement, it is necessary to act energetically, taking care however, not to set up superficial ulceration. In this case the does varies from 7 H. to 10 H., according to the particular case and the stage of the integuments.

In very serious cases progressing rapidly it may be advisable to exceed these quantities, for a radiodermatitis is of little importance when compared with so formidable a disease. We therefore seek to circumscribe and arrest its evolution, even at the cost of severe reaction. Even then we must not allow the reaction to exceed a superficial erosion. We shall give more precise details when we come to study the various diseases which are amenable to radiotherapeutic treatment.

We may repeat that, as a rule, the dose for an adult should not exceed 9 H. or 10 H., and that this dose should only be given when the severity of the disease demands energetic intervention.

A most important point is the time which should elapse between each exposure when the total quantity required is so great that it must be given in several instalments.

Béclère's experience leads to the conclusion that the interval between two séances should be about seven days.

The interval should evidently depend on the quantity absorbed during each séance. If the dose is small, producing merely a slight erythema, the interval between the exposures may be shortened. When the dose has been considerable, the interval of seven days advocated by *Béclère* is in our opinion rather too short. The reaction in many cases only attains its maximum in ten to twenty days; it is often scarcely visible on the seventh day, especially if the dose was a large one.

In such cases the appearance of the lesion on the seventh day would not guide us in our future treatment.

Usually we separate successive irradiations by an interval of from ten to fifteen days. If the previous dose was a large one,

such as is given for epithelioma or cancer of the breast, we increase the interval to twenty days. We repeat the dose only when the reaction is slight, or has partially subsided. Further details will be given in a subsequent chapter.

These, then, are the two important factors in radiotherapy—quantity and quality.

A knowledge of these two data will enable us to reproduce the same conditions, and therefore to produce the same effects and with the same therapeutic results. They are strictly scientific data because they apply to the X-rays themselves, and are not dependent on the apparatus which produces them.

Information can now be given in formulæ such as the following: 'To clear an obstinate patch of psoriasis on the knee we must administer from 4 H. to 5 H. of Holzknecht's units, the rays having a penetration corresponding to No. 5 or No. 6 on Benoist's radiochromometer.'

With such data the physician can use any form of focus-tube; he may use either an induction-coil or a Wimshurst; his static machine may be a very powerful one or it may be only a small four-plate machine; he may place his focus-tube at whatever distance from the skin he prefers; in a word, he may vary at will all the technical conditions of the operation, and yet he will always secure the desired result so long as he is careful to adjust these two factors correctly: the quality of the rays and the quantity absorbed.

Next in importance to these are the biological factors; both quality and quantity require slight modifications according to the sex and age of the patient, the region treated, and the nature of the disease.

We do not desire to condemn those who think it advisable to record the electric constants and the different measurements of time and distance which are noted during their treatment.

Such data are of interest, since they enable one to realize the experimental conditions under which the operation took place, but they are of no value as a means of comparing results. They are valuable for the experimenter's private use, since they refer to his own installation, but they give no useful information to the reader.

Quantity and quality are the only data of universal importance.

CHAPTER VII

METHOD OF APPLICATION

Since the discovery of the Roentgen rays, the methods of application for therapeutic purposes have been of the most varied description. Each operator has followed a method of his own, as may be seen by anyone who cares to read the records published during the last few years.

Usually the authors indicate, with more or less detail, the electric constants of the apparatus they employ, with the occasional addition of the time of exposure and the distance of the patient from the tube.

It is obvious that these data are of no value to anyone but the author himself, who can always employ the same apparatus under similar conditions. Since, however, exact measurements are the exception in these reports, and more precise data are unavailable, we must content ourselves with any details we can obtain of the particular installation employed.

In 1898 *Schiff* and *Freund* employed hard tubes in their radiotherapeutic practice. For some years they had maintained that equally good results were obtainable with hard and with soft tubes, although the effects of the latter were more rapid. They used a Ruhmkorff coil, giving a 12-inch spark, which was supplied from the public mains, or from a battery of accumulators.

The primary current was of an intensity of $1\frac{1}{2}$ to 3 ampères, with 16 interruptions per second. A hard tube was used, producing rays of a high degree of penetration, which was so adjusted that the rays fell directly on the surface to be treated. At the beginning of the séance the tube was placed at a distance of 6 inches from the skin, and was gradually approached to a distance of 2 inches. The duration of exposure varied from five to ten minutes.

In his work published in 1903 *Freund* indicates the modifications which he has introduced into his former method. Following *Scholtz's* example, he employs soft focus-tubes, commencing with an intense exposure at a short distance, and then diminishing the duration and increasing the distance at each subsequent séance.

Both of these authors advocate frequent exposures, each of short duration, repeated until the occurrence of reaction. On the appearance of the first symptoms of reaction they stop the treatment. They assert that the effects of the irradiations continue for some considerable time after the treatment has been stopped. A similar method is employed by many other practitioners—by *Müller*, *Grouven*, *Havas*, *Pusey*, *Zechmeister*, *Merk*, *Török*, *Schein*, *Gastou*, *Vieira*, *Hall-Edwards*, *Boczar*, and others.

Schiff has recourse to preliminary irradiation to determine the susceptibility of his patient to the action of the rays. He also recommends the use of hard tubes, in order to avoid any danger of too intense a reaction.

Gassmann and *Schenkel* follow a procedure very like that of *Schiff*. They use a coil giving an 18-inch spark, with a current in the primary of 3 or 4 ampères, at a pressure of 30 volts, and a break interruption of 20 to 30 per second. With this current the anticathode becomes red hot. The séances are continued until the occurrence of the first signs of reaction.

Scholtz, who was a pupil of *Neisser*, uses a soft focus-tube, and employs instruments of exact measurement in his radiotherapeutic practice. The following is his method of procedure: 'In order to determine the sensibility of the skin, we commence with a preliminary irradiation of feeble intensity. This is especially necessary in the treatment of acne, hypertrichosis, eczema, and folliculitis of the beard. After a few days' interval we give a fairly strong exposure, in order to set up the desired degree of reaction as rapidly as possible. At each succeeding séance we diminish the intensity of the irradiation. The final exposures are of moderate intensity, and are continued until the desired degree of reaction is attained.

'This method is midway between that employed by *Schiff* and *Freund*, and the technique followed by *Kienböck*. We thus attain the desired effect as quickly as possible; we no longer work in the dark, and so run no risk of producing accidental dermatitis. Moreover, we avoid the unpleasant experience of finding, after two

or three weeks' delay, that our irradiation has not been of sufficient intensity.

'Our method of procedure is in accordance with theory. In dealing with a drug which is tardy and cumulative in its action, one does not commence with a small dose, and then increase the dose progressively. It is usual to commence with a large dose, and diminish the subsequent doses little by little.

'The frequency of the séances depends on circumstances. Suppose we have a child in hospital suffering from favus: we wish to produce an epilation of the scalp. The first exposure would be one of fifteen minutes' duration, with the anticathode at a distance of 12 inches, or an exposure of ten minutes' duration, with a distance of 10 inches. On each succeeding day a shorter exposure would be given. Later on the séances would be on alternate days, and later still on every third day, while the duration of exposure would be gradually diminished to five, and ultimately to three, minutes.

'When the hairs begin to fall out, which usually occurs at the end of the second or at the commencement of the third week, the irradiations are suspended, and the epilation will be completed without the occurrence of serious dermatitis.

'Suppose now the same child comes as an out-patient. The first exposure is of the same duration and at the same distance as before, but for the convenience of the patient the subsequent irradiations are somewhat less frequent. During the first week the séances are repeated at intervals of two or three days, each lasting for six or seven minutes. During the second week the séances occur every four days for four or five minutes, at a distance of 12 inches. *Mutatis mutandis*, the same procedure is employed for lupus, sycosis, psoriasis, etc.'

In conclusion, *Scholtz* adds a paragraph on the determination of the best distance of the anticathode from the skin: 'A considerable distance—12 to 18 inches—should intervene when the surface to be irradiated is extensive, especially when the dose indicated is moderate, as in epilation and widespread psoriasis. By this means we equalize the intensity over the whole area, and even convex regions like the scalp may be comparatively uniformly irradiated. The rays should, as far as possible, fall perpendicularly on the skin. A lupus of the nose should be irradiated on either side, or better still, on the dorsum and on either lateral face successively.'

Gron of Christiania employs soft tubes in radiotherapy. He uses a coil with a current of 3 or 4 ampères and a pressure of 110 volts, and varies the duration of exposure from ten to fifteen minutes. The distance of the anticathode from the skin is 6 to 10 inches. The adjacent skin is protected by a sheet of lead, and the séances are continued until reaction occurs. This is merely a variation of *Schiff's* method.

Morton of New York prefers a soft focus-tube for the treatment of skin diseases, whereas he uses a hard tube when he desires to attack a deeply-seated tumour. He strongly insists upon the necessity of using instruments of exact measurement. His séances, which are of six to eight minutes' duration, are repeated three times a week, and he does not stop the treatment on the appearance of reaction. On the contrary, he persists till the first slight erythema becomes of a deep red or even a dark tan colour. Once this tan-coloured pigmentation has been produced, the skin can support a considerable dose of X-rays without injury. In this way *Morton* endeavours to harden the skin, and only stops the treatment on the occurrence of slight dermatitis.

In his most interesting work, *Williams* does not attempt to give any definite measurements. He takes note of the condition and appearance of the focus-tube, and is thus able to estimate roughly the quantity of rays that are absorbed for a given result.

Experience and the prolonged use of the same installation render it possible for him to determine this point without the use of measuring instruments. He uses a coil with a current of 5 ampères at 220 volts in the primary, or, by preference, a static machine.

In his opinion, the duration of exposure, the distance of the tube, and the frequency of the séances should be determined for each individual, for each installation, and for each disease. In general, a soft tube should be used, with a distance of 6 to 8 inches from the anticathode to the skin, and the séances should be repeated two or three times a week, with an exposure of from five to twenty minutes each time. On the appearance of redness or bronzing, the séances should be suspended until all signs of reaction have disappeared. The occurrence of dermatitis is more especially to be avoided in cases of a benignant nature.

Stelwagon also uses a soft tube, whose equivalent spark-length is about 2 inches. In this he agrees with *Pusey*, *Hyde* and *Montgomery*, *Pfahler*, *Léonard Sweet*, *Allen*, and others. During the

first fortnight *Stelwagon* gives two séances a week of five minutes' duration each, with a distance of 10 to 12 inches. If no reaction or improvement occurs, he increases the exposures to three a week, each of ten minutes' duration. The distance is reduced to 8 inches, and finally to 5 inches. If this has no effect, the duration is increased to fifteen or twenty minutes, and the exposures are repeated until slight erythema is produced. Occasionally a more severe dermatitis sets in, which necessitates an interruption of the treatment. This is generally followed by the rapid amelioration of the disease. The séances are renewed as soon as the reaction has disappeared, and little by little the lesion begins to heal.

Kienböck, in his report to the Congress at Grenoble, thus describes the technique he employs: 'We use a very powerful coil, giving a spark of 16 to 20 inches, with a mercury or an electrolytic break, giving a high frequency of interruption. We employ a regulating-tube made by Müller of Hamburg, and we maintain this in a moderately soft state, regulating the current so as to give the maximum illumination. If the morbid condition is of small extent, we bring the tube as close as possible to the patient's skin, and we are thus able to reduce the length of exposure to a few minutes. If the disease is of larger extent, the tube must be placed further off, in order to equalize the intensity of the rays over the whole irradiating surface. If the area to be treated is of very large extent, it may be necessary to alter the position of the tube from time to time. The healthy skin around the diseased area is protected by a plate of lead, 25 millimetres thick, which is covered on both sides with a sheet of caoutchouc. This protects the skin from sparks, and can easily be cleaned when required.

'At each séance the dosage may be varied in various ways:

1. 'The magnitude of the irradiation depends on the quality and intensity of the X-rays, the distance of the anticathode from the skin, and the duration of the exposure. As we rarely alter the quality and quantity of the rays, or the frequency of interruption, and only slightly vary the distance of the tube from the skin, we are able to adjust the dose by altering the duration of the exposure. This is usually from five to fifteen minutes.

2. 'The most scientific mode of estimating the dose is that invented by *Holzknecht*. By the side of the irradiated area is placed a pastille. This contains a reagent, which is coloured of a more or less deep shade of green according to the amount of

X-rays absorbed by the pastille, and consequently by the adjacent skin. The colour acquired by the pastille is compared with the different tints on a graduated scale which serves as a standard, and the exposure is continued until the required depth of coloration is obtained. This chromoradiometer, as it is called, enables us to measure the quantity of rays absorbed by the skin, and hence the intensity of the exposure. This measurement is quite independent of the resistance of the focus-tube or the frequency of the interruptions in the primary circuit, the effective duration of an exposure being represented by the total number of X-ray emissions which strike the skin.

3. 'A third means of measurement has been devised by *Freund*, who uses a 2 per cent. solution of iodoform in chloroform. This liquid acquires a red colour under the influence of the X-rays, the depth of the coloration increasing during an exposure.'

Kienböck then proceeds to define the doses of X-rays. 'A small normal exposure' is one which produces a reaction of the first degree. It is an absorption of 3 H. units during an irradiation of six minutes. A 'normal exposure,' or a 'medium normal exposure,' is one that will produce a slight reaction of the second degree. It consists of an absorption of 4 H., the exposure lasting from seven or eight minutes. A 'strong normal exposure' is one that will produce a more marked reaction of the second degree, with an absorption of 5 H. in the course of nine or ten minutes. Finally, 'a double normal exposure' will produce a reaction of the third degree, 8 H. being absorbed in a period of fifteen minutes.

This question of dose is of the greatest importance. 'What dose should be given during a radiotherapeutic exposure? At what intervals should the séances succeed one another? How many exposures should be given?'

The answer to these questions cannot be given categorically. It must depend on circumstances.

There are some affections of the skin which are curable by a radiodermatitis of the second degree. This may be produced by a single normal exposure of eight minutes' duration with the absorption of a dose of 4 H.

There are other diseases which require for their cure an acute dermatitis repeated every two months.

On the other hand, there are certain affections of the skin in

which an acute reaction should be avoided, but where we endeavour to set up a chronic dermatitis with a slow course of evolution. This may be effected by exposures of medium intensity more frequently repeated—perhaps as often as once a week.

Finally, in some affections we desire to obtain the degenerative action of the X-rays without any inflammatory reaction. For this purpose, a slight reaction at long intervals, of a fortnight or more, is all that is required.

In France the method most generally employed is that of *Oudin*, which we will proceed to describe.

In *Oudin's* opinion, a most important indication is the colour of the anticathode, which becomes heated by the bombardment of the cathode rays. This should be of a deep cerise tint. The tube he uses is a soft one, and should be brought as close as possible to the skin—'just at the nearest point,' says *Oudin*, 'at which no spark can strike across from the tube, and where the radiating cone of X-rays will embrace the whole surface to be treated.' The distance between the wall of the tube and the skin may be as little as 5 centimetres. In consequence the duration of exposure is much diminished, and may be counted by seconds instead of minutes. The length of exposure may be gradually increased, but must never exceed five minutes.

The following is his method of procedure:

'The first séance is of only thirty seconds' duration. After an interval of forty-eight hours I give a second exposure of one minute, and after another interval of forty-eight hours, a third exposure of a minute and a half. I proceed in this manner, adding half a minute every other day, until the duration of exposure reaches three minutes. At that point I suspend the séances for a week. If there are no signs of irritation, I recommence with three minutes, and increase gradually up to five minutes—a duration of exposure which I never exceed.

'If at any time slight redness and itching occurs, I suspend the séances until these have completely disappeared. On recommencing, I am careful not to begin with a long exposure, especially if the lesion is superficial. If I am treating a deep-seated lesion, I increase the dose gradually, stopping again on the occurrence of erythema.'

At the meeting of the Société de Dermatologie of March, 1904, *Oudin* thus expresses himself: 'I employ a focus-tube the resist-

ance of which can be maintained constant by an osmo-regulator so as to give an equivalent spark of 2 to 5 centimetres. For superficial affection, I use rays of a penetration of No. 5 to No. 7 on Benoist's radiochromometer. For deeper lesions I use rays of No. 7 to No. 10 on the same scale. The tube is placed as near as possible to the skin, so as to illuminate the whole diseased area, usually 5 to 10 centimetres from the latter. The séances are repeated every second day, beginning with very short exposures of from two to four minutes. At each succeeding séance, I increase the time of exposure by half a minute, and I continue the treatment until the appearance of an erythema. Under the circumstances of its production this erythema is usually benign, commences from twelve to twenty-four hours after an exposure, is accompanied by some slight heat and itching, and disappears in the course of a few hours. The production of this erythema is the basis of my treatment. It acts as a sort of touchstone by which I regulate the duration of the séances and the intervals between them. I endeavour to produce it systematically, and am thus independent of measurements of voltage and ampèrage, which however, I keep constant as far as possible. In every case I know that the erythema will appear after so many minutes' exposure. This, which I may call the critical exposure, I repeat for several séances when I wish to provoke a simple radiodermatitis. In most cases—and I think this is the better plan—I give exposures just short of this. In the production of this benign dermatitis, I often notice a personal co-efficient which varies in different individuals. This idiosyncrasy is as well marked in these cases of benignant erythema as it is doubtful in the severer forms of dermatitis.

As regards *Holzknecht's* chromoradiometer, *Oudin* finds it of doubtful value. In his opinion it is very difficult to use, and its indications are not very exact.

Gaston and *Vieira* follow *Schiff's* method, the only difference being that the séances occur on alternate days with a duration of ten minutes, and are continued till reaction appears.

At St. Louis, *Sabouraud* employs the following method in the treatment of tinea by epilation: He gives the required dose of the rays at a single sitting, and awaits the result. This is the method that we recommended when he sent *Dr. Noiré* to the Broca Institute to study our technique.

At St. Louis a statical machine is used for the production of the

X-rays, which have a penetration of No. 4 or No. 5 on Benoist's scale. The dose is measured in Holzknecht units.

Haret and *Desfosses* give a number of short séances several times in the week. In this way they cause the absorption of a quantity of rays equal to 16 H. in a month, stopping the treatment when the lesion is somewhat modified. With this treatment they obtained good results in a case of cutaneous epithelioma which was exhibited to the Société médicale des Hôpitaux in January, 1904.

Dr. Béclère bases his method on the two following rules:

1. To give at each sitting the maximum quantity of X-rays compatible with the integrity of the skin or mucous membrane irradiated.

2. To make the interval between the séances as short as is compatible with the integrity of the skin and mucous membrane.

In order to comply with the first rule, he makes use of *Holzknecht's* apparatus for measurement, but he relies chiefly on the results of his own observation and personal experience.

'To comply with the second rule,' he says, 'I find by experience that an interval of a week is usually required. This period of seven days is not invariable, however. At the commencement of the treatment, when the gravity of the case seems to require it, I frequently give two séances each week for a week or two. Very exceptionally I give three séances in a week, at the risk of setting up a certain degree of dermatitis. In a severe case this is justifiable, just as in syphilis we run the risk of producing salivation rather than that of administering too small a dose of mercury. On the occurrence of dermatitis, I either diminish the weekly dose or increase the interval between the séances. On very rare occasions I have been compelled to intermit the treatment until the reddened and desquamated skin has regained its normal condition. In the cases which I have treated myself, some fifty in number, I have never set up an ulcerative dermatitis. By rigorously following the rule of a seven days' interval, I believe I might have avoided even the slighter cases of dermatitis that I have met with; since many of my patients, with weekly séances, have been able to continue the treatment for many months without inconvenience or interruption.'

Kienböck has shown that the methods employed by different observers fall naturally into three classes:

First Class.—A small dose is given every day, and this is repeated

until the occurrence of reaction. The length of exposure is so adjusted as to cause a slight erythema at the end of a fortnight.

Second Class.—The second class is subdivided. Some authorities give irradiations of moderate intensity twice a week until the occurrence of reaction. Others give a medium exposure for two, three, four, or five consecutive days, and then await reaction.

Third Class.—This is the method which *Kienböck* himself advocates. He gives the necessary quantity of X-rays at a single sitting, and then awaits the reaction.

This is a useful classification, but not a perfect one, as the methods used by some authorities do not find a place in any of the above classes.

In our opinion, radiotherapeutic methods may be arranged in two principal groups, each group being in its turn subdivided.

The first embraces all those methods in which the irradiation is continued until the occurrence of reaction.

There are three subdivisions of this method:

1. Irradiations of very feeble intensity are repeated every day.

2. The treatment is begun by very feeble irradiations, which are increased day by day.

3. The early irradiations are of medium strength, and the dose is gradually diminished.

The second main group consists of those methods in which the necessary dose is given, and then the operator waits for the occurrence of reaction before proceeding further. There are two subdivisions:

1. Massive dose—when the full dose is given at a single sitting.

2. Fractional doses—when the required dose is given during several séances.

The methods of the first category are open to several objections. In radiotherapy it is dangerous to go to work blindly. This is what is done when we continue the irradiations daily until the actual occurrence of erythema. We must remember that there is a well-defined stage of latency between the periods of action and reaction. This stage is longer or shorter according to the intensity of irradiation. In giving daily séances until reaction occurs, we must remember that the cutaneous symptoms only appear from seven to fifteen days after the skin has absorbed the dose necessary to produce the required reaction. If we continue treatment till reaction occurs, it is evident that the irradiations given during

these last seven to fifteen days are superfluous, and by their addition to the reactionary dose will increase the inflammatory symptoms. It is true that by employing small or diminishing doses this danger is minimized. Even then, as *Kienböck* has pointed out, this method is tedious and is unnecessarily fatiguing both to doctor and patient. It is still worse if the doses are progressively increased. It is sometimes said that the patient may become gradually habituated to stronger and stronger doses; this, however, is not the case. There is, on the contrary, a cumulative action. Moreover, the skin will be exposed to the more intense irradiations towards the end of the treatment, when the dose already absorbed has been sufficient to determine a dermatitis. Although the exposures may cease when erythema occurs, the reaction will not stop there; a radiodermatitis will occur, which may result in terrible ulceration, since the later and stronger irradiations have been day by day adding their effect to the reactionary dose during the latent period. This alone is enough to condemn the method of procedure by increasing doses.

The methods of the second class are more scientific, since they accord better with the use of exact instruments of measurements. The dose necessary to produce a given result is determined once for all. We endeavour to cause the absorption of the exact dose and wait for the desired effect. Frequently, however, the quantity of X-rays necessary to cure a given lesion will be greatly in excess of any dose compatible with the integrity of the integument.

In that event we give the maximum dose which can be absorbed without injury to the skin. *Sabouraud*, *Béclère*, and others give this dose at a single sitting. *Kienböck* points out that to do this with safety requires great experience on the part of the operator. For our part we are very much of his opinion, but once this experience has been attained, the method gives a wonderful facility for treatment, especially in hospital cases, the number of which increases day by day. If the installation at our disposal is not a very powerful one, it may be difficult to give the necessary quantity at a single séance. In that case we may give consecutive sittings for two or three days, so that the total quantity of rays absorbed shall be slightly in excess of that which would have been given at a single exposure. After this, we have nothing to do but to watch the case carefully and wait patiently for any manifestations of reaction. When these subside, we recommence the treatment again as often as necessary.

There are some objections to this method. The patients are only treated at intervals of a fortnight or more, for a period of half to three-quarters of an hour. For some imaginative patients, in private practice especially, this treatment does not seem to be active enough. It is, however, an advantage in hospital practice, since the patients are not taken away from their work more than twice a month.

It may be objected that precious time may be lost by following this method. For instance, in a case of epithelioma, it is judged necessary to give a periodic dose of 6 H. This quantity is given in two séances, and we await the result. After fifteen to twenty days, it is found that this quantity is not sufficient to produce the necessary reaction and the lesion is unaffected. The treatment has to be recommenced with a stronger dose after the loss of fifteen days.

In this case the fault does not rest with the method, but depends on an error in the determination of the dose.

Instead of giving the dose in one or two séances, it may be given in six or seven sittings, separated by two or three days' interval. The intensity of each application must be such that the sum of all the irradiations will equal the quantity of X-rays required. This is *Scholtz's* method. It has the same advantages as the single massive dose, but requires the expenditure of more time on the part of both doctor and patient. The patient's visits will be more frequent, and moreover the sum of the fractional doses should be slightly in excess of the quantity which would have been given in one exposure when the single massive dose is employed.

Kienböck has shown the same quantity of rays will produce a different effect according to whether they are absorbed at one exposure or in five or six séances, separated by an interval of several days.

In general, the reaction is less marked when the irradiation is given in fractional doses. According to our own observations it would appear that the quantity of a single massive dose must be increased by one-quarter in order to get analogous results with fractional doses. On the other hand, the patient is much less fatigued by a series of short exposures, he is better interested in the treatment, and is encouraged by more frequent interviews with the doctor. The fractional method is therefore preferable when patients live at no great distance. It is moreover, indicated in cases where the rays are used for the alleviation of pain or pruritus,

since frequent séances are more likely to maintain the sedative effect of the X-rays.

It is evident that we must not blindly follow the same technique in every case. As *Grubbe* and *Williams* remind us, each individual case should be studied independently, and our methods must be varied from time to time in order to get the best results. It is very evident that totally different procedures are required in the case of a limited cutaneous epithelioma, and that of a painful carcinoma of the breast. In the former case a single massive dose will probably prove successful; in the second case fractional doses must be given in order to allay the pain. Again, frequent small doses are indicated in those cases where there is risk of the absorption of morbid products or toxins.

The Reaction.—Is it necessary to set up a visible reaction in radiotherapeutic treatment?

The answer to this question is not easy. As *Schiff* says, the ideal method for epilation would be to cause the hairs to fall out without any accompanying erythema, or any vesiculation or cutaneous atrophy. The attainment of this ideal is unfortunately very difficult, if not impossible. There is great difference of opinion as to the necessity of producing reaction in the treatment of skin diseases, or the destruction of morbid growths.

Dickson and others consider that marked reaction is to be avoided.

Williams, in his last work on the X-rays, repeats his opinion given in 1901: 'In order to get the best therapeutic results, violent reaction is quite unnecessary. In certain malignant neoplasms however, where the skin is intact, he thinks it may be advantageous 'to drain the tumour' by making a communication between it and the surface. This may be done either by a surgical incision or by a small Roentgen ulcer properly produced. By this means the toxins resulting from the destructive action of rays on the cancer cells are eliminated, instead of being carried into the circulation.

In the treatment of neoplasms, *Morton* advises that the irradiation be continued even after the occurrence of dermatitis.

Most practitioners of radiotherapy endeavour to set up a slight cutaneous reaction, and then intermit the treatment until all inflammatory reaction has ceased. We are of opinion that the exposure should be continued in spite of reaction, in the treatment

of lesions, such as epithelioma and sarcoma, in which the rays may be supposed to have an eliminating action. A certain degree of erythema, or even a slight inflammatory reaction, is of advantage in such cases. In more severe lesions, such as carcinoma of the breast, a still more active treatment may be necessary.

We are, however, far from advising the production of ulceration or sloughing in any case. The production of dermatitis is only permissible in very exceptional cases, necessitated by the gravity or extent of the lesion. Usually we stop at the first sign of erythema, and in certain cases even this should be avoided. The physician may not in every case be able to cure; he must never injure. In the portion of this work devoted to the radiotherapy of skin diseases we shall indicate more in detail the exact stage of reaction at which the treatment should be discontinued in each case.

The Author's Method.—In *Dr. Brocque's* electrotherapeutic department at the Broca Hospital we follow a method very similar to that of *Kienböck*, subject, however, to modifications according to the nature of the case to be treated. It is a most excellent technique for hospital patients, enabling us to treat a large number of cases effectually in a limited time, and guarding against the danger of accidental dermatitis. It has been gradually evolved from a long series of experiments and therapeutic observations.

We carefully examine the patient and the lesion from which he is suffering, and thus determine in advance the dose which is necessary to produce a definite result—either complete resolution, if this can be obtained without setting up dermatitis, or a certain degree of reaction, if the total dose would be too great to be given with safety to the skin. For instance, we know that a dose of 5 or 6 H. is sufficient to completely clear up a patch of psoriasis without serious reaction. We therefore submit the lesion to an exposure of 6 H., with rays of a suitable degree of penetration. If, on the other hand, we are treating a case of epithelioma of the skin, the total dose would be much too large to give at a single sitting.

It may be impossible to determine *a priori* the quantity of rays required. In this case we administer the largest dose compatible with the integrity of the integuments, say 7 or 8 H. If the epithelioma is already ulcerated, this may be increased to 10 or 11 H.

The dose once determined, we administer it in a single exposure, or in the course of two séances, separated by an interval of twenty-

four hours. There is no therapeutic advantage in giving two exposures. If the dose is a small one and can be given in a reasonable time, there is no object to be gained by spreading it over two sittings. If the quantity is larger, it may be necessary to give the dose on two occasions in order to diminish the fatigue of a protracted sitting. In reality there is no difference in the two methods, and it is only the limited power of our apparatus that obliges us in certain cases to give a second exposure. The only point to be taken into consideration is the magnitude of the total dose absorbed by the skin. The effects in both cases are absolutely identical, whether we give 10 H. at a single sitting or 5 H. on two occasions with an interval of twenty-four hours between them.

On the evening of the exposure we may occasionally observe a slight erythema over the irradiated area. This occurs just as frequently after a single exposure as after a double one. We have already given an explanation of this phenomenon, which should not be regarded as contraindicating the second exposure.

The required dose having been absorbed by the skin, we tell the patient to return in ten or twelve days if the irradiation has been a slight one, or in fifteen to twenty days if the exposure has been more prolonged.

During this interval he is directed to note the changes—erythema, itching, etc.—which supervene in the irradiated area. At his return we examine the lesion, of which a tracing and photograph have been taken, and we note the state of the disease and the degree of reaction. If, for example, the case is one of epithelioma and the surface is still red, itching, squamous, or weeping, we wait until the symptoms are ameliorated before proceeding to another exposure.

If, on the contrary, the reaction was slight, and if the redness is abating and has almost disappeared, we submit the lesion to a second exposure, giving the same dose as on the first occasion. Once again we await the apparition and subsequent disappearance of reaction, and so on for as long as is necessary. In short, it is the attenuation of the phenomena of reaction, their disappearance, or their non-appearance which guide us in the application of the X-rays. By this means all cumulative action is avoided, and the irradiation is carried out in a scientific manner. During the course of treatment described the lesions have been modified in appearance, the morbid tissues have begun to disappear, and the ulcerations have cicatrized.

We then begin to diminish the dose, basing our practice on the fact that a skin which has been already irradiated is more sensitive than one which is in its virgin state, and has never been exposed to the X-rays. As the process of healing progresses, we increase the intervals between the séances, and even after the reparative action is accomplished, we give an occasional slight exposure in order to complete the cure and obviate any danger of relapse.

When the process of healing is completed, we cease all treatment, recommending the patient to return from time to time in order to watch the case.

Our procedure is founded on the following principles:

1. To cause the skin to absorb the full dose necessary for a cure in the shortest possible time, if that dose is compatible with the integrity of the skin. If this is not the case, to give at each exposure, or at each series of exposures, the largest dose which is compatible with the integrity of the integument.

2. To give each subsequent exposure only after an interval of ten to twenty days; to await the subsidence of reaction before recommencing the treatment, and to vary the dose according to the condition of the tissues and the appearance of the lesion.

In this manner we have treated a large number of patients with satisfactory results without any occurrence of serious radiodermatitis. In the cases where reaction has been somewhat energetic, it has been purposely excited in order to obtain the more rapid destruction of morbid growths. In determining the appropriate dose, we have to consider the appearance of the integument, the nature of the lesion, the region of the body, and the age and sex of the patient. In any case of doubt it is better to give too little rather than too much.

In doubtful cases, when the skin appears very sensitive and the lesion irritable, we follow the example of *Schiff*, and give a preliminary exposure. By this means we measure the patient's susceptibility, and can then proceed more boldly. In treating widely-spread affections like psoriasis or mycosis fungoides, we give a daily séance, directing the irradiation on a different area each day, but giving each area its appropriate dose. We do not repeat the irradiation on any one spot until all symptoms of reaction have disappeared. We have never seen any traces of the supposed ill-effects of X-rays on the general health. We have at the present time several patients who have for many months absorbed an average of

150 H. per month on different areas of the body without ill-effects. One patient, who has been treated for mycosis fungoides with very satisfactory results, has absorbed 1,200 H. without any violent reaction, and without any ill-effect on the general health. The estimated quantity of X-rays, 1,200 H., is well below the mark, for we have not taken into consideration the area of the irradiated regions. In order to get the true amount of X-rays absorbed in a given case, we must take into our calculation the area of the irradiated surface as compared with the unit of surface—*i.e.*, the area of a Holzknecht pastille. In that case the estimate of the quantity absorbed would be increased four or five fold.

It is evident that any possible influence of the X-rays on the general health must depend on the total quantity of rays absorbed. If a surface 10 centimetres square is irradiated with the same intensity as a surface 2 centimetres square, the amount absorbed by the organism will be much greater in the former case. We would strongly emphasize our opinion that the scientific application of the X-rays must be based on the use of instruments of exact measurement. Only on this condition can radiotherapy emerge from the domain of empiricism, where it has so long sojourned, into the clear light of science.

CHAPTER VIII

INDICATIONS FOR THE USE OF RADIOTHERAPY

Since *Freund's* inception of radiotherapy in 1896, the list of diseases treated by the X-rays has been increased till it contains almost every possible dermatosis, and a great number of other affections. As *Leredde* well says, radiotherapy, like every other physical discovery, has been the subject of many illusions. Whenever a new treatment has yielded satisfactory results in a particular class of cases, the special conditions are speedily forgotten, and the method is used at all hazards for every possible affection.

Two considerations appeared to point to the Roentgen rays as a possible source of therapeutic action: one was the discovery of their superficial action on the skin, and the other their penetrative power.

The X-rays proved to be a potent agent in the treatment of skin diseases, but it was hoped that they would have a more profound action on lesions inaccessible to ordinary therapeutic agents. Hence the numberless attempts to treat pulmonary tuberculosis by this means.

One after another, all the diseases which had resisted ordinary therapeutic treatment were submitted to the action of the rays, in the hope that the new form of energy might perchance influence them. Some affections were ameliorated, some were unaffected, while others were aggravated. The results of these experiments were speedily published, but since we had as yet no measuring instruments, it was impossible to describe the technique employed in each case. Thus we were unable to repeat an experiment under similar conditions. This may in some degree explain the contradictory results obtained in these early experiments.

If one could understand the mechanism of the action of X-rays

one might hope to define theoretically the morbid affections for which they should be of use. Unfortunately we have only hypothesis to guide us in this matter. We do not even know what particular elements of the tissues the X-rays attack by preference. We can only have recourse to a series of systematic therapeutic experiments to determine what diseases are susceptible to treatment by X-rays.

Radiotherapy has extended its field of action very gradually. When favourable results have been observed in one class of cases, it has been tried in analogous disorders. In this manner *Perthes* of Leipzig was induced to try the X-rays for the cure of cancer, a papilloma on his own hand having disappeared after a slight attack of radiodermatitis. In the same way *Schiff* was led to use X-rays for epilation by observing the shedding of the hair in a case of nævus pilorus.

Opinions differed greatly as to the indications for radiotherapy. As early as 1901 *Hahn* gave it as his opinion that the X-rays were only useful in the treatment of lupus, and that it caused injury in other skin diseases on account of the severity of the reaction. At that date *Schiff* was already treating many varieties of skin diseases by radiotherapy, and was hoping to apply it to the cure of deep ulcerations of mucous membranes which were not amenable to other treatment.

About the same time *London*, at the Russian Medical Congress at St. Petersburg, declared that radiotherapy had a great advantage over phototherapy, since the action of the latter is limited to a small area, and to the superficial layers of the skin, whereas the X-rays act over a larger area, and penetrate to a greater depth.

In 1902 *Scholtz* published a long list of the different varieties of dermatosis which he had treated by this method. These were lupus vulgaris, lupus erythematosus, favus, tinea, sycosis, acne vulgaris, acne rosacea, eczema, psoriasis, nævus, verneæ, prurigo, pruritus, lichen, lichen ruber, pemphigus, lepra, mycosis fungoides, carcinoma of the skin, and hypertrichosis.

Freund has attempted to classify the diseases amenable to X-ray treatment in accordance with the action of the rays themselves. The Roentgen rays act in two distinct ways, according to the magnitude of the dose employed. In small doses they produce irritation and alterative action on the structures of the skin. In

larger doses their action is destructive, and this disintegrating action is usually limited to certain elements of the skin.

In certain cases the X-rays, like many chemical substances, produce an irritative action on the tissues, stimulate connective tissue cells, and produce cicatricial tissue.

Freund's classification is as follows :

1. Diseases of the hair, of the scalp, and other regions covered with hair. This division includes all those affections in which an epilation is required, in addition to the specific action of the X-rays on the tissues of the skin. These diseases are: favus, parasitic sycosis, non-parasitic sycosis, folliculitis of the beard, blepharitis, papillary dermatitis of the scalp, tinea, hypertrichosis, herpes tonsurans, and pelade.

2. The second group comprises the ulcerative affections of the skin. These may be divided into the non-infectious ulcerations, on which the X-rays exercise a favourable stimulating action, and the infectious ulcerations of the skin, which require in addition the destructive action of the rays on the histological elements of the lesion and arrest of the morbid growth. These are: lupus vulgaris, scrofuloderma, cutaneous tuberculosis, epithelioma, rodent ulcer, lepra, mycosis fungoides, atonic and varicose ulcers, perforating ulcers, etc.

3. The third division comprises the inflammatory diseases of the skin, whether acute or chronic, and the granulomata. These are: eczema, psoriasis, prurigo, lichen ruber planus, pemphigus, lupus erythematosus, furunculosis, acne vulgaris, and acne rosacea.

The mechanism of the successful results of radiotherapy in these cases is not well understood. *Freund* considers that it is due to the electric effleuves from the tube.

4. In the fourth category are placed the various dermatoses resulting from vascular alterations and vascular nævi, etc.

5. In the fifth division we find the lesions due to a progressive disturbance of the nutrition of the skin, verrucæ, nævi pilosi, and elephantiasis.

In a similar manner *Kienböck* has arranged the diseases susceptible of radiotherapeutic treatment in four distinct groups:

Group A.—Hypertrichosis, alopecia areata, canities circumscripta, trichorrhexis nodosa, favus, tinea tonsurans, folliculitis.

Group B.—Acne rosacea, comedones, eczema, verruca, lichen ruber, prurigo, pruritus, hyperhidrosis, psoriasis.

Group C.—Condyloma acuminata, gumma, syphilitic ulceration, lepra, trachoma of the conjunctiva, lupus erythematosus, lupus vulgaris, scrofuloderma.

Group D.—Mycosis fungoides, epithelioma, carcinoma, sarcoma.

In America *Pusey* has attempted to arrange the diseases in which radiotherapy is indicated, according to the biological action of the Roentgen rays.

According to him, the rays produce the following effects :

1. Atrophy of the skin and its appendages.
2. Destruction of microbes in living tissue.
3. Alterations of metabolism.
4. Destruction of certain pathological formations.
5. Anodyne action on the pain of malignant tumours, on neuralgia, and on pruritus.

These various physiological actions are indicated in the treatment of the following diseases :

1. Hypertrichosis, affections of the scalp (tinea, sycosis, favus, etc.), ablation of the nails, atrophy or decreased activity of the sebaceous glands, comedones, acne, lupus erythematosus, lichen planus, psoriasis.
2. Destruction of microbes, lupus.
3. Influence on nutrition of the skin, eczema, lupus erythematosus, lichen planus, psoriasis.
4. Destruction of tissues with feeble resistance, carcinoma.
5. Anodyne action on pain and pruritus.

We append a list of the affections treated in the Massachusetts Hospital at Boston by *J. T. Bowen* in 1903 :

Epithelioma.
Subcutaneous carcinoma.
Senile keratosis.
Lupus vulgaris.
Sarcoma.
Folliculitis.
Eczema.
Psoriasis.
Varicose ulcer.
Acne.
Hypertrichosis.
Alopecia.

Erythema induratum.
Scleroderma.
Hyperhidrosis.
Aïnhum.

Most of these affections have been favourably influenced by radiotherapeutic treatment. Some, however, and especially the last three diseases, have not been in any way modified.

In his admirable work, 'The Roentgen Rays in Medicine and Surgery,' *Williams* classes the affections in which the X-rays have proved useful in the following manner:

I. *Cutaneous Inflammations.*

Intertrigo.
Herpes zoster.
Psoriasis.
Eczema.
Acne vulgaris.
Acne rosacea.
Prurigo.
Pemphigus.
Lichen ruber planus.

II. *Hypertrophies.*

Elephantiasis.
Verrucæ.
Keratosis.

III. *Atrophies.*

Pelade.
Alopecia.

IV. *Painful Dermatoses.*

Pruritus ani.
Pruritus vulvæ.

V. *Parasitic Affection.*

Cutaneous diseases due to blastomycetes.

VI. *New Growths*

Cancer.
Keloid.
Lupus vulgaris.
Lupus erythematosus.
Lepra.
Mycosis fungoides.
Goître.
Thyroid hypertrophy.
Pulmonary tuberculosis.
Chronic peritoneal tuberculosis.
Adenitis.
Tubercular sinuses.
Chronic ulcerations.
Hodgkin's disease.
Diseases of the cornea.

In France one of the first works on this subject was *Oudin's* article in *Bouchard's* 'Traité de Radiologie médicale.' The author briefly reviews some of the principal diseases on which the X-rays have a therapeutic effect.

These are :

Tuberculosis.
Articular affections.
Diseases of the bones.
Hypertrichosis.
Acne.
Furunculosis.
Lupus vulgaris.
Lupus erythematosus.

'I have purposely omitted,' says *Oudin* in his chapter on radiotherapy, 'some of the applications of the X-rays, such as affections of the eye, pleurisy, ulcers of the stomach, cerebral tumours, and syphilitic ulcers. Even baldness has been treated by the Roentgen rays. In all of these cases however, there is no precise information as to the effect of radiotherapy.'

In an article entitled, 'The Present State of Radiotherapy in Cutaneous Affections,' which appeared in October, 1903, *Leredde* complains of the abuse of the X-rays in the treatment of affections

to which they can afford no possible amelioration. If people would give up regarding the X-rays as a universal panacea, and reflect on their mode of action, it would be seen that the whole of the inflammatory and temporary affections of the skin are outside their sphere of action. Their activity and penetration, which makes them so powerful a means of treatment in the hands of the dermatologist, and the fact that their successful application needs long experience, prevent their use in slight cases. Radiotherapy should be reserved for the treatment of serious and obstinate dermatoses which have resisted ordinary therapeutic measures.

He classes the diseases suitable for radiotherapeutic treatment in three main groups.

1. In treatment of the diseases of the first group, it is necessary to produce a destruction of tissue. Hence we need not take any precautions against the occurrence of ulceration. The tube is brought close up to the patient, and the exposures are of relatively long duration. Cutaneous cancer is a typical lesion belonging to this group.

2. In the second group it is desired to produce a profound modification rather than a destruction of the elements which constitute the lesion, and the substitution of a hardened cicatricial tissue in the place of the pathological formation. Lupus is the typical disease of this group. In treatment, the irradiation should be made with caution, so as to avoid too violent reaction.

3. In the third group we endeavour to produce a slight superficial lesion of a temporary character. This should only slightly modify the vitality of the tissue without the production of scarring. Hypertrichosis is the typical affection belonging to this group. In its treatment the séances should be of short duration, and the tube should be placed at some distance from the patient.

In the opinion of this author, the number of diseases in which radiotherapy is indicated is somewhat restricted, cutaneous epithelioma, lupus, hypertrichosis, favus, tinea and nævus being the only affections in which the new method of treatment can be employed with advantage. Even in these diseases, the results are not always satisfactory.

All the foregoing classifications are necessarily imperfect, none of them being founded on data which are generally recognised. Some are incomplete, whilst others unite in one group diseases which are widely different in their nature.

The last, that of *Leredde*, is perhaps the least open to objection, because it is the vaguest of them all. But it groups together hypertrichosis, eczema, and nævus, affections on which X-rays do not produce the same effects, and which should not be treated in the same manner.

He also places epithelioma in the first category, that of lesions in which it is desired to produce destruction of tissue and ulceration; but in the treatment of cutaneous epithelioma the ulceration is only accidental, and it is rarely necessary to produce it.

Until we know more of the mechanism of the X-rays, it will be wiser to base our indications for treatment on the knowledge of the facts already acquired by experience.

This is the opinion of *Dr. Béclère*, who divides all cutaneous diseases into two classes: those in which we can foretell the results of radiotherapeutic treatment from a knowledge of the physiological effects of the Roentgen rays, and those in which theory does not enable us to foresee any special action.

The only physiological effects of the X-rays that we can recognise with certainty are the various modifications which the healthy skin undergoes—*i.e.*, rubefaction, epilation, vesiculation, ulceration, and sloughing. The diseases in which it is desired to obtain one of these reactions may be grouped in the first category. Diseases of the hair may also be placed in this group. There are two affections in which epilation is indicated—viz., diseases of the hair, and excessive development of the capillary system. Hypertrichosis, tinea, sycosis, and all the parasitic affections of the hair, belong to this category.

To the second class belong all those affections in which *a priori* we should imagine the X-rays would have no influence, and in which the occurrence of a favourable result came rather as a surprise to the operator.

Thus *Freund* employed radiotherapy in the treatment of sycosis, because he had witnessed beforehand the epilating action of the X-rays; whereas favourable results in the treatment of epithelioma could not have been foreseen.

It may be objected that this division is not a true classification. Although we do not understand the mechanism of the action of the rays, yet we do know that they have a sort of selective affinity for pathological tissue. This is not the same for all varieties of patho-

logical growth, and hence some forms of neoplasm do not appear to be influenced by them.

In the present state of our knowledge, it is more logical not to base a classification on unproved hypotheses. We know that X-rays have a favourable action on certain affections; we do not know why this is so, and the same may be said of many older therapeutic agents.

The Roentgen rays are as yet but imperfectly understood; they are difficult to manage, and their use demands prudence and intelligence on the part of the operator. One of the most fundamental rules of the prudent physician is never to take a risk where but little is to be gained. It would, therefore, be absurd to apply radiotherapy to every slight case of eczema, or psoriasis, or varicose ulcer. It is by such promiscuous use that the new method is prejudiced. The X-rays should be reserved for serious cases in which other therapeutic measures have failed. It is quite legitimate to treat epithelioma of the skin by radiotherapy, not only because of the uncertainty of all other methods of treatment, but also on account of the admirable cosmetic results of radiotherapy in these cases. Tinea and favus should also be treated by this method, because it is the only means of insuring a complete and rapid epilation. Eczema and psoriasis should be treated by the usual therapeutic methods; only in grave and recurring forms, when all other methods have failed, should we turn for assistance to radiotherapy. In many cases its use will be followed by amelioration and cure; occasionally the lesions will remain stationary, or even be aggravated by the use of the Roentgen rays.

The physician who would engage in the practice of radiotherapy cannot exercise too great prudence—a prudence induced not by fear, but by wisdom. In the first place, he must thoroughly understand the technology of the apparatus he employs, and the use of the instruments of precision and measurement. Without this preliminary knowledge he is working in the dark, and only courts disaster. In the second place, he should commence with caution, using only moderate doses. If there is any question as to the sensibility of the skin, a preliminary experimental irradiation should be given, as recommended by *Schiff* and *Freund*. He will gradually become accustomed to the management of the rays, and able to adjust the doses required by the various lesions he is called upon to treat.

It is very probable that he will meet with failures. He need not be discouraged, but should note them honestly, and search diligently for the cause. Sometimes they result from some defect in technique, more often from the nature of the lesion itself. In outward appearance this may be similar to others which yield readily to the rays, but it may in reality be of totally different origin, or under different conditions of development. Further light on this subject can only come from careful clinical observations and experiment, which alone can furnish us with the precise indications for radiotherapeutic treatment.

In the third part of this book, the clinical portion, we shall pass in review the various diseases for which radiotherapy has been found useful, and describe the therapeutic results we have met with in our own practice. A number of photographic illustrations will, it is hoped, render this part of the subject more intelligible to the reader.

PART III

CHAPTER I

INSTALLATION USED BY THE AUTHOR

Before proceeding to the study of the affections which are susceptible of treatment by radiotherapy, we may rapidly describe the technical conditions under which our own clinical results have been obtained, and the installation at our disposal.

The greater part of our therapeutic work has been done in the laboratory of *Dr. Brocq* at the Broca Hospital.

We have at our disposal two radiotherapeutic installations, the one driven by a coil, the other by a static machine. In both cases a Chabaud focus-tube with Villard's osmo-regulator is employed.

The high-tension apparatus is one of Gaiffe's coils with open magnetic circuit. This gives a 10-inch spark, and is driven by a battery of eight accumulators, with a current in the primary of 5 ampères, and a pressure of 16 volts. We use a mercury break of Gaiffe's original pattern, with metallic plunger, with gives 800 to 2,000 interruptions per minute. A regulating rheostat enables us to maintain the frequency of the break at about 1,600 per minute. The output of energy, and hence the wattage in the primary circuit, is kept constant by regulating the depth to which the plunger dips into the vessel of mercury, and by altering the resistance of the circuit.

The inverse current is arrested by the introduction of a Villard's valve into the course of the positive lead.

The resistance of the focus-tube is measured by means of a spintermeter mounted in parallel with it. This has ball terminals 1 centimetre in diameter.

A Destot and Williams detonator is introduced into the secondary circuit in the course of the positive rheophore. When the spark-gap of the detonator is opened, the current passes in a

continuous stream of sparks. In consequence of the increased resistance thus obtained, the focus-tube produces rays of greater penetration, as may be shown by means of the radiochromometer.

The following is a table showing the penetration of the rays corresponding to different lengths of the equivalent spark. The penetration is given in degrees of Benoist's chromoradiometer, and the table is constructed for the Chabaud focus-tube actually in use in our installation :

Length of the Equivalent Spark.	Penetration on Benoist's Scale.
6 centimetres	9
5 ,,	7 to 8
4 ,,	6
3 ,,	4 to 5
2 ,,	3

While keeping the primary current and the quality of the rays constant, we determined the number of Holzknecht units absorbed by the skin, at a fixed distance, in a given time. As a result of repeated experiments, we have drawn up the following table, showing the quantity of radiation absorbed for rays of medium penetration, Nos. 4 and 5 on Benoist's scale, when the anticathode is at a distance of 12 centimetres from the skin :

Time.	No. of Holzknecht's Units absorbed.
15 minutes	4 to 5 H.
20 ,,	6 to 7 H.
25 ,,	8 to 9 H.
30 ,,	10 H.

On account of the position or area of the lesion, it may sometimes be necessary to place the focus-tube at a greater distance from the skin. In this case we may calculate the quantity of rays absorbed by applying the law of the inverse square of the distance, and may verify our calculation by means of a Holzknecht pastille placed on the skin. The amount of rays absorbed in a given time is estimated by comparing the pastille with the standard scale. If the duration of exposure and the distance of the tube are noted, the determination will enable us to give a similar dose on another occasion.

By this means we do not need to employ a fresh pastille for each

case. The observation should, however, be repeated every eight or ten days, so that we may be sure that none of the conditions have altered.

Besides the installation we have just described, we have a second apparatus, the current for which is supplied by one of Gaiffe's ten-plate static machines. This is rotated by an electric motor, which in its turn is driven by a continuous current from the public mains. The following are the values on Benoist's scale of the penetration of the rays, employing Chabaud's focus-tube :

Length of Equivalent Spark.	Penetration on Benoist's Scale.
4 centimetres	7 to 8
3 „	6
2 „	4 to 5

Taking rays of medium intensity, No. 5 on Benoist's scale, we have the following table for the quantity absorbed in terms of Holzknecht's units :

Time.	No. of Units absorbed.
15 minutes	5 to 6 H.
20 „	7 to 8 H.
30 „	10 to 12 H.

In our earlier radiotherapeutic treatment, the focus-tube was fixed in an ordinary tube-holder designed by *Dr. Béclère.* This was not entirely satisfactory, as one had to use plates of lead to shield the patient from the rays. Moreover, it was difficult in many cases to bring the tube close up to the patient. We therefore constructed a wooden box covered with lead to contain the focus-tube. This was afterwards replaced by the localizer which we use at the present time. The apparatus is easily adjustable by means of a multiple joint, and an improved clamping arrangement ensures the requisite rigidity.

Position of the Patient.

As a rule it is better to place the patient on a hard couch, so that he may remain perfectly immobile. In certain cases the sitting posture is more convenient, especially in irradiation of the scalp. The patient should be properly supported, so that he may

not move. In this respect the tube of the localizer in direct contact with the region to be treated is very convenient. By this device *Sabouraud* secures immobility during the irradiation of children affected with ringworm. It is important to place the patient in a position which he can conveniently maintain during the whole time of exposure.

The diseased region should be carefully examined, and the diagnosis if possible confirmed by histological methods. A tracing or photograph of the lesion should be taken in every instance.

The parts around the diseased region should be carefully shielded from the action of the rays, but we usually irradiate an area rather larger than the affected surface. By this means any morbid foci in the neighbourhood of the diseased patch will be equally attacked. The protection of neighbouring parts is best effected by means of a lead plate. An orifice, which should be rather larger than the diseased area, permits the rays to reach the surface which we desire to irradiate.

The sheet of lead should be flexible, but it should be thick enough to arrest the superfluous rays completely. Ordinary tin-foil is useless, and so is very thin lead-foil. The best means of ensuring the proper thickness is to test the shield with a fluorescent screen. Messrs. Drault prepare leaden shields covered on either side with a layer of caoutchouc, as recommended by *Dr. Béclère.*

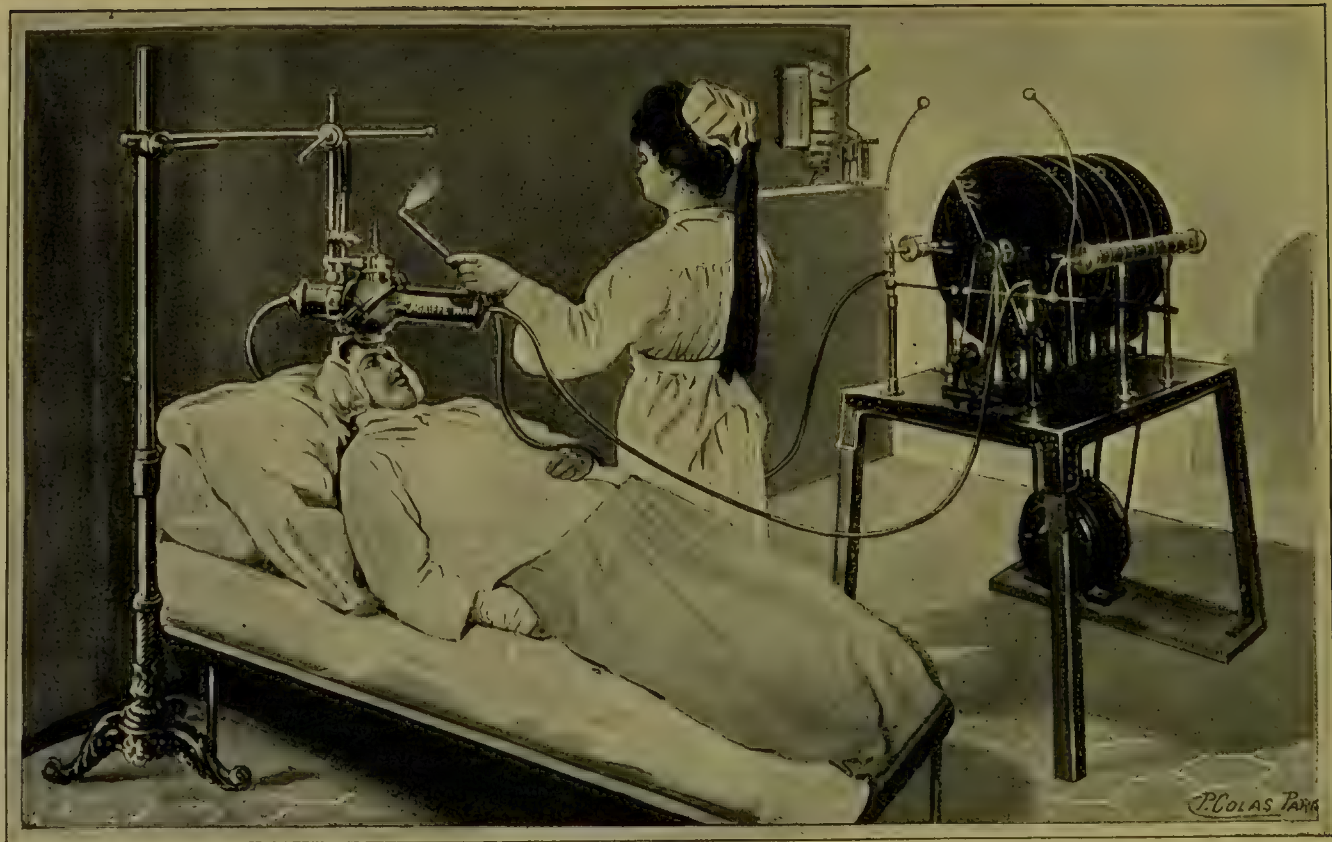
In the instrument we now use, the tube of the localizer replaces the leaden shield, the patient being no longer burdened by a sheet of metal, which is heavy, disagreeable, and difficult to keep clean. Before use the tubes may be rendered aseptic by being dipped into alcohol and ignited.

It is of great importance to centre the focus of the rays accurately with regard to the lesion, and to adjust the anticathode at the required distance from the skin.

The distance should be reduced as much as possible, always bearing in mind the law we have already enunciated: 'The distance of the anticathode from the skin should not be less than twice the diameter of the area to be irradiated.' By this means when treating a plane or concave surface we get an illumination which is sensibly uniform. Where a convex surface of large extent is to be irradiated, it should be divided into several segments, each one of which may be treated separately.

By the use of our localizer the correct distance of the tube

PLATE IV.



VIEW OF THE INSTALMENT AT THE BROCA HOSPITAL WITH BELOT'S LOCALIZER (HORIZONTAL POSITION).

To face p. 220.

PLATE V.

BELOT'S LOCALIZER IN A VERTICAL POSITION.

The patient is the one mentioned in Case 1, suffering from mycosis fungoides.

To back p. 221.

is adjusted mechanically, in consequence of the due proportion between the diameter and length of each tube.

When all the adjustments have been completed, the patient is brought into the room, and we proceed with the exposure.

The time is accurately measured by means of a stop-watch, and a gas-jet is in readiness wherewith to heat the osmo-regulator, so as to maintain the vacuum in the tube as constant as possible. Directly a spark passes in the spintermeter, the platinum tube is heated until the sparks cease, when the flame is at once removed. By this means we avoid all danger of making the vacuum too low and the tube too soft, and the constant use of the radiochromometer becomes superfluous. In practice the tube is found to get harder, and never softer, during use.

Radiodosometric Charts.

In an interesting communication dated April, 1904, *Dr. Béclère* described a chart for the registration of the duration and frequency of the séances in radiotherapeutic treatment.

'I have,' he says, 'designed a graphic method for facilitating the registration and comparison of radiotherapeutic treatment by different practitioners, and *Dr. Haret* has lithographed the charts, which I submit to your notice.'

The radiodosometric charts are analogous to temperature charts, which exhibit at a glance the temperature variations in the course of a fever. They are traversed by vertical and horizontal lines. The horizontal distances represent intervals of time, and the vertical, the quantities of X-rays absorbed, each division corresponding to one Holzknecht unit. The whole course of treatment may thus be represented by a graph which usually takes the form of series steps, the height of each step representing the quantity of rays, and the breadth the interval between the exposures. I hope in future that all reports of Roentgen treatment will be accompanied by one of these charts.

On p. 223 we give one of these radiodosometric charts, showing the curve of treatment in a case of cutaneous epithelioma.

It may serve as a model for those who wish to keep a record of treatment. It is superfluous to insist on the advantages of this chart, and its cost alone has prevented our using it in all our own reports. In the following pages we shall not enter into the details

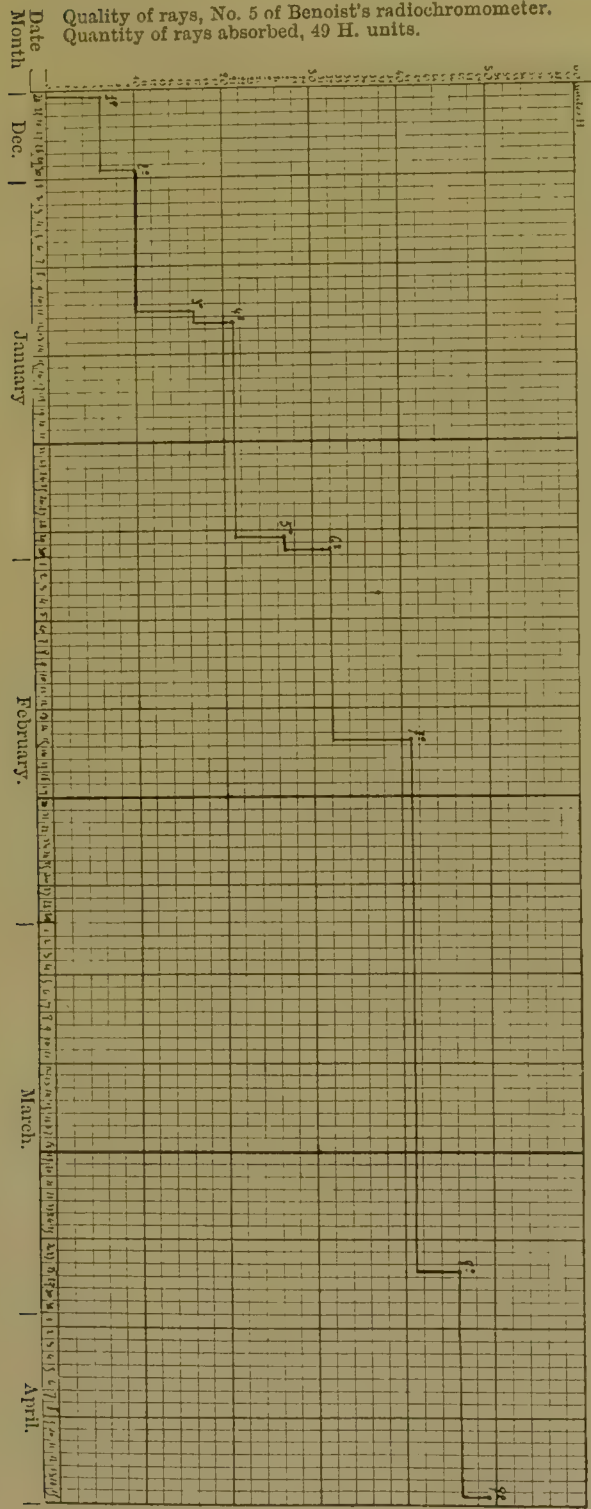
of all the cases we have treated, as such a course would be tedious and void of interest. We shall only give a résumé of the more interesting of these.

The skin diseases which may be advantageously treated by radiotherapy may be divided into eight groups.

This must not be regarded, however, as a systematic classification, since all methods of classification are necessarily incomplete. We have merely grouped together those diseases on which the X-rays appear to exercise a similar effect.

MADAME M——, FIFTY-SEVEN YEARS.

Quality of rays, No. 5 of Benoist's radiochromometer.
Quantity of rays absorbed, 49 H. units.



No. 2.

RADIODOSOMETRIC CHART.

Cutaneous Epithelioma.

RADIODOSOMETRIC CURVE.

This curve is reported in Case II., Cutaneous Epithelioma (Photograph, Plate X.).

TABLE SHOWING CASES TREATED IN THE LABORATORY OF DR. BROCQ, AT THE BROCA HOSPITAL, FROM MAY, 1903, TO JUNE, 1904.

	Number.	Cured.	Improved.	Aggravated.	Stationary.	Relapsed.	Treatment Abandoned.	Still under Treatment.	Observations.
Trichophyties	6	4	1	—	—	—	1	1	
Favus	3	1	—	—	—	—	1	1	
Sycosis	2	1	1	—	—	—	—	1	The improved case is almost cured
Hypertrichosis... ...	3	—	1	—	1	—	1	—	
Pelade	3	—	1	—	—	—	2	1	
Psoriasis	4	2	—	—	—	1	1	1	
Seborrhœa	2	1	1	—	—	1	—	1	
Pruritus	2	2	—	—	—	—	—	—	
Lichenification... ...	6	2	4	—	—	1	—	5	The parts treated have lost their lichenoid appearance
Prurigo—Hebra's ...	1	—	1	—	—	—	—	1	The regions treated are healed
Eczema—patches ...	4	—	1	—	—	—	—	3	The objective symptoms are cured
Lichen planus	2	1	1	—	—	—	—	1	
Lichen corneus ...	1	1	—	—	—	—	—	—	The elements treated are cured
Scleroderma	2	—	2	—	—	—	—	2	Some patches are much improved
Keloid	5	2	1	—	—	—	—	3	
Nævus	1	—	1	—	—	—	—	1	
Verrucæ	6	5	—	—	—	—	1	—	
Lupus vulgaris ...	6	—	3	—	—	—	2	4	One case almost cured
Lupus erythematosus...	4	—	2	—	1	—	1	—	
Mycosis fungoides ...	2	—	2	—	—	—	—	2	The parts treated have totally disappeared
Sarcoma—cutaneous ...	1	—	1	—	—	—	—	—	The objective symptoms are cured
Lympho-sarcoma ...	1	—	1	—	—	—	—	1	
Sarcoma	2	—	2	—	—	—	—	2	
Epithelioma—cutaneous	27	15	7	—	—	—	4	8	Some of the improved cases are almost cured
Epithelioma—tongue ...	2	—	1	—	—	—	—	2	
Epithelioma—eyelid ...	1	—	1	—	—	—	—	1	
Cancer—after operation	2	—	2	—	—	—	—	2	
Cancer of the breast ...	6	—	2	—	3	—	—	5	One case died of pleurisy
Carcinoma	1	—	—	—	1	—	—	1	
Telangiectases	1	—	—	—	—	—	1	—	
Parapsoriasis	1	—	1	—	—	—	—	1	The parts treated are healed
Keratosis pilaris ...	1	—	1	—	—	—	—	—	
Raynaud's disease ...	1	—	—	—	1	—	—	1	
Scrofuloderma	1	—	1	—	—	—	—	—	Died outside the hospital

CHAPTER II

DISEASES OF THE PILO-SEBACEOUS SYSTEM

1. The X-Rays as an Epilating Agent

In 1896 the early experimenters with X-rays found that the hair was shed on those parts of the body which were exposed to their action.

The first observations on this subject were published by *John Daniel* in April, 1896. He noticed that twenty-one days after the scalp of a child had been exposed to the rays, the whole of the hair was shed without the occurrence of erythema or pain. Soon afterwards similar observations were recorded by other experimenters.

From this time epilation by means of the X-rays became a legitimate mode of treatment. This method of epilation was soon extended not only to cases of disease of the hair and of the hairy follicles, but also to those affections in which the hair itself was a source of irritation. Later on the X-rays were used in hypertrichosis, where an exaggerated development of the hair itself was a cause of disfigurement.

Finally, the X-rays were employed in all cases in which depilation was indicated, either for hypertrichosis or for parasitic diseases of the scalp and beard, such as favus, tinea, sycosis, folliculitis, and blepharitis.

To *Schiff* and *Freund* of Vienna belongs the honour of first employing the rays in the treatment of disease. They were the pioneers who showed the way to many followers in the therapeutic application of Roentgen's discovery.

It was at first much disputed whether the rapidity of epilation was in any way affected by the quality of the X-rays. At the present day it is admitted that the most active radiations in this respect are those which possess the lowest degree of penetration.

This must necessarily be the case, since only those rays which have little penetrative power are absorbed in their passage through the skin. It is better to use those of a moderate degree of penetration however, since the softer rays are apt to produce serious reaction. We consider that rays corresponding to Nos. 5 and 6 on Benoist's scale are most suitable for the production of depilation, and in this we are in accordance with *Sabouraud's* opinion on the subject.

It is impossible to fix a maximum or minimum for the distance of the anticathode from the skin, since this will differ according to the size of the area to be treated. It is evident that in order to obtain a uniform action over the whole surface, the irradiation should be the same on each unit of area. To insure this in the case of a plane or concave surface, the distance from anticathode to skin should be twice the diameter of the area to be irradiated. To facilitate the equable irradiation of a convex surface, the area treated at one exposure must be diminished, or else the distance of the tube must be increased, the duration of the exposure being increased in proportion to the square of the distance.

It will be interesting to inquire into the mechanism of the shedding of the hair after irradiation. Is it destruction, burning, or a sort of withering of the hair by the action of the rays?

As is well known, the hair papilla is very sensitive to the action of irritants of all kinds. Probably the irritation set up by the X-rays is concentrated on the papilla itself, and the arrest in the growth of hair is a secondary consequence of this irritation. *Sabouraud* explains the action in the following words: 'The hair papilla is extremely sensitive: any suspension of its function causes the death and shedding of the hair itself, and the most diverse causes are sufficient to suspend its power of producing a hair. In the neighbourhood of a boil, for instance, it is not unusual to see the shedding of a patch of hair, which however, is soon reproduced. In this case the papilla may be said to have undergone a sort of temporary withering, and in the same way it may be supposed to wither temporarily under the action of the X-rays. This seems to be the true explanation of the destructive action on the papillæ, which gradually lose their function, the hairs responding to the slow disintegration by a progressive shrinking and thinning of their roots. When the papilla ceases its work of reproduction, the hair dies and becomes a foreign body, to be ejected by the surrounding tissue. The epidermic tube, which is an inversion of the integu-

ment like the finger of a glove, eliminates the hair little by little, and is itself effaced in the process. After a short time, a club-shaped bud of epithelial tissue is all that remains of the atrophied follicle. This bud develops into a new papilla, which in its turn produces a new hair.'

One can easily understand that a different technique must be employed according as it is desired to produce a permanent alopecia or a temporary epilation for the cure of tinea, sycosis, or favus.

Radiotherapy has also a beneficial effect on the various lesions of the skin which accompany diseases of the hair. In the treatment of those regions of the body which are specially sensitive to the X-rays, great care is requisite in order to guard against the occurrence of accidental dermatitis. We will now proceed to a more detailed consideration of those affections of the hair which have proved amenable to the action of the Roentgen rays.

Hypertrichosis.

Only a few months after Roentgen's discovery, *Schiff* and *Freund* applied the X-rays to the treatment of hypertrichosis. From a technical point of view, it appeared vastly superior to any of the previous methods for the treatment of this anomaly. Depilatories and other topical applications are unsatisfactory in their action, and frequently set up symptoms of general poisoning, or local irritation of the skin. Moreover, with the exception of electrolysis, none of these applications produces a permanent alopecia. When a comparison is made between the use of electrolysis and radiotherapy, all the advantages would seem to be on the side of the latter. By the use of the X-rays a surface of considerable extent may be thoroughly and rapidly denuded, the finest down and the coarsest hairs being alike destroyed. Moreover, the pain of electrolytic treatment is avoided, as well as the scarring to which it gives rise.

For some time radiotherapy has been considered the ideal method of epilation in cases of hypertrichosis. *Schiff* and *Freund* obtained remarkable success, and the numberless papers which they published on the subject testify to their enthusiasm. In 1903 *Freund* thus describes the method he employed with so much success:

'I use a hard tube,' he says, 'showing only a faint greenish fluorescence. This is driven by a 12-inch coil, with a current of 2 or 3 ampères and a pressure of 110 volts. The distance between the tube and the skin is 6 inches. The exposures are of short duration, and are repeated daily until the appearance of slight discoloration of the skin. The hairs fall out after twenty to twenty-five sittings. They are shed *en masse*, and are found adhering to the towel after washing. The roots are completely atrophied. There is sometimes slight desquamation, accompanied by a sensation of burning, but usually the skin remains smooth and white. Pigmentation also occurs frequently in patients of dark complexion. All these symptoms abate in the course of five to eight days, and the skin regains its normal appearance.'

Freund has observed a curious phenomenon—viz., that the dark hairs become snow-white for some days before they are shed.

Unfortunately, in the treatment of hypertrichosis, it is not enough to cause the hairs to fall out; we must prevent them from growing again. It is well known that the alopecia produced by the X-rays is at first a temporary one, and only becomes permanent when the reaction has been severe enough to produce complete destruction of the hair follicles. Moreover, this destruction cannot be produced without a certain amount of atrophic change in the integument, with consequent ulceration and scarring. Hence we need to seek for a safer way of preventing the regrowth of the hair. After the X-rays have produced a primary shedding of the hair, a series of shorter exposures, frequently repeated, are given, in order to produce a gradual atrophy of the papilla without injury to the skin.

The following are *Freund's* remarks on this subject:

'If the treatment is not continued, new hairs begin to appear as a fine down on the surface of the skin in from five to eight weeks after the hairs have been shed. In most of the cases we have treated, we have been able to prevent this regrowth by giving one or two supplementary exposures once a month, after the epilation is completed. In all cases in which these supplementary exposures have been omitted there has been a regrowth of hair two months after the cessation of treatment. To insure a permanent result, the supplementary irradiations should be continued for a period of twelve to eighteen months. It would seem that a very slight

irradiation is sufficient to maintain the alteration in the papilla which prevents the regrowth of hair.

'In this way I have obtained favourable results in a large number of cases, some of which have had no recurrence after an interval of two years.

'The skin, which is at first tense and slightly atrophic, regains its normal appearance in the course of a few months. All that remain are a few small white atrophic spots, indicating the position of the hair follicles. These also disappear in the course of time.

'The results are most satisfactory when the exposures have been just sufficient to produce epilation without any superficial reaction of the skin.'

Schiff and *Freund* both speak very highly of this mode of treatment for hypertrichosis, and assert that they have never met with an unfavourable result. *Freund*, however, reports the case of a young woman of fair complexion who was treated for hypertrichosis of the forearm, with the result that a number of brown pigmented spots appeared on the irradiated area, and only disappeared after the lapse of some considerable time. In the course of his practice he has never met with the complications of a sclerotic type, or the elephantiasis described by *Balzar* and *Mouseaux*, *Salomon*, *Barthélemy*, *Behrend*, *Hallopeau* and *Gadeau*.

Jutassy reports forty-four cases of hypertrichosis, in all of which he endeavoured so to adjust the exposure as to be just sufficient for epilation and no more. The method he employed was that of *Schiff* and *Freund*. The dose of X-rays was so proportioned as to set up chronic inflammation and consequent degeneration of the hair papilla. In this way he was able to effect permanent epilation, without any regrowth of the hair and without setting up a radiodermatitis. He insists on the need of caution, especially in the case of young subjects, who are influenced more readily than those of maturer years. He considers, moreover, that patients of light complexion react more violently than brunettes. In his experience the stronger hairs are destroyed more easily than the finer down on the surface of the skin. He agrees with *Kienböck's* observation that reaction is more marked in the centre of an irradiated area, and hence he concludes that those rays are the most potent which fall perpendicularly. We have, however, shown in a former chapter that this effect is really due to the fact that a greater quantity of

the radiation is absorbed by the central portion of an irradiated surface.

Kienböck is far from being equally enthusiastic, although he has also attained excellent results. In the year 1901 he expressed himself thus:

'When we are called upon to treat hypertrichosis of the face in a female patient, we must remember that a single series of exposures will only produce a temporary alopecia, unless a severe dermatitis has been set up. This should be avoided at all costs, since such a reaction may result in atrophy of the skin and scarring. In the generality of cases a permanent alopecia cannot be obtained in less than a year or so of treatment, during which time the hair may be prevented from growing by repeated irradiations of slight intensity. This is our only means of avoiding dangerous accidental dermatitis.

'In most cases the cosmetic result of radiotherapy is most satisfactory, but it is well to be on one's guard against the occurrence of pigmentation and other affections of the irradiated area when the treatment has been prolonged.'

In 1902, at the Congress of Berne, *Kienböck* considerably modified these opinions. He thought that only the more serious cases of hypertrichosis should be treated by X-rays, since the alopecia is sometimes followed by a certain amount of atrophy of the skin, and in some cases by telangiectasis, pigmentation, and other symptoms of so-called 'late reaction.'

At the Congress at Grenoble in 1904, he reports: 'Hypertrichosis of the face in female patients should not be treated by X-rays. In order to produce epilation and prevent the regrowth, we have to set up repeated attacks of radiodermatitis of the second or third degree. These may result in cyanosis, or finally in atrophy of the skin, with pigmentation and telangiectasis. Even after a single normal exposure of 4 H. to 6 H., cutaneous atrophy may occur as a "late symptom," which may increase for many months.'

Holzknecht does not speak so strongly, although he acknowledges the great difficulties which beset the radiotherapeutic treatment of hypertrichosis. He says a different technique should be employed according as the patient is a young girl or a woman of maturer years.

With patients of middle age, after the menopause, a single dose

of 3 H. to 5 H. may be absorbed by the skin. After an interval of some weeks, a second exposure may be given, and this may be repeated three or four times.

Slight inflammatory reaction follows, the hairs fall out, and after the third or fourth application, a slight degree of cutaneous atrophy results. The treatment must then be suspended, and continued later if circumstances require it.

In the case of young girls who present symptoms of hypertrichosis at the age of puberty, *Holzknecht* recommends either of two different methods. The first is to give an exposure of 3 H., then wait six or eight weeks before proceeding to a second irradiation, and repeat the process from five to fifteen times. The second method is to treat the case with fractional doses of 2 H., repeated every two or three weeks for a period of six months. The treatment is then interrupted for two months, and the cycle begun again. By this means all danger of pigmentation and cutaneous atrophy is avoided.

Oudin has published notes of an experiment on a young man in whom he obtained a partial epilation of the forearm. Daily irradiations were given. On the first occasion the length of exposure was three minutes, and the duration was increased each day by thirty seconds, until a maximum of four and a half minutes was reached. The hairs began to fall out after the fifteenth exposure, and continued to do so till the twentieth day. Unfortunately, in consequence of his leaving Paris, the experiment could not be carried further.

In America, *Pusey* reports two cases of complete and permanent cure of hypertrichosis. The first case, that of a young girl with hypertrichosis of the upper lip and chin, was completely cured after eighty-five séances. The second patient had sixty-seven applications, the only reaction being a slight erythema and pigmentation.

Satisfactory results have been reported from various countries—Germany, England, America, Switzerland, and Hungary. Among others, we may mention the names of *Ehrmann*, *Grunmach*, *Grouven*, *Hahn*, *Lévy-Dorn*, *Benedikt*, *Sjögren* and *Sederholm*, *Durnstrey*, *Sharpe*, *Ullmann*, *Neville Wood*, *James Startin*, *Havas*, *Lancashire* and *Kaposi*.

Jutassy and *K. Minich* made a histological examination of sections of the skin of a rabbit which had been subjected to epilation by the X-rays. They report: 'The Malpighian layer

is separated from the underlying dermis by a nearly straight line, only interrupted here and there by a few follicles, more or less deeply embedded in the dermis. For the most part they are situated in the superficial layer of the dermis. The lumen is in all cases completely obliterated, and cell débris or atrophied epidermic cells take the place of hairs. Here and there a few follicles penetrate to the deeper layers of the dermis and contain the débris of dark-coloured hairs; these do not, however, reach as far as the papilla.

'The papilla itself is atrophied. The hairs, which are normally thickly clustered, are here few and far between. The hair follicles are not to be seen, and are replaced by connective tissue rich in cellular elements.

'In the deeper layers grains of pigment occur. The vessels here are much dilated and filled with blood-corpuscles, but not thrombosed. The nerves seem swollen, but are not otherwise affected. The most essential alteration appears to be the atrophy of the hair follicles and of the papillæ.'

Observations similar to the foregoing have been made by *Zemman.*

In cases of hypertrichosis, some physicians employ a mixed treatment, using electrolysis as well as radiotherapy. Thus *Walsh* commences with a series of radiotherapeutic exposures, and after some weeks, when the hairs are loose, he proceeds to the electrolysis of the hair follicle after extraction of the hair.

It is difficult to find one's way in the midst of all these observations and experiments. It is important, however, to keep the main object well in view.

The successful treatment of hypertrichosis must fulfil two conditions—the production of a permanent alopecia and the avoidance of cutaneous reaction.

The depilating action of the rays is efficacious enough, but unfortunately the hairs begin to grow again after a period of some seven to ten weeks. In this respect the new procedure is inferior to electrolysis, and in order to make the former a success, we must discover a means of arresting the new growth of hair. This is the problem which *Dr. Brocq* submitted to the Société de Dermatologie in 1902. 'Dermatologists,' he says, 'will be very cautious in making use of this method, until X-ray specialists are agreed on the precise technique to be employed. We trust they will speedily be able to determine the procedure to be followed in

order to obtain a temporary depilation in such cases as tinea or favus without injury to the hair, as well as the method to be employed for the production of a permanent alopecia in cases of hypertrichosis.

At the present time, although we can attain with certainty the former of these requirements—*i.e.*, a temporary epilation—we are not able as yet to produce a permanent alopecia without danger to the integument.

This is the crux of the whole matter. Hypertrichosis is not so much a disease as a disfigurement. The patients who ask our assistance are mostly young girls or women who have a more or less well-developed beard, growing on the face, the cheeks, the lips, or the chin. This anomalous and disfiguring growth has a profound effect on their nervous system. At any price they ask to be cured, and their request is a perfectly legitimate one. The face may be restored to its pristine beauty by the destruction of the beard. But what if this result be followed by the production of scarring, of hyperpigmentation, and telangiectasis? The appearance of the poor woman will be rendered worse than it was before. Even temporarily, it is annoying for a woman to have her face disfigured by an acute erythema or hyperpigmentation. The ideal result is for there to be no visible reaction during the whole course of treatment. Is this result possible?

The destruction of atrophy of the hair papilla is a *sine quâ non* in the production of permanent alopecia. It is easy to effect this destruction rapidly by setting up a violent dermatitis, but this result would be deplorable, since scars, pigmentation, and discoloration are worse than the hypertrichosis. For this reason the irradiation must be a very gentle one, so as only to irritate the papilla, to wither it up, and thus cause the hair to fall out. Afterwards, when the new hairs begin to grow, a series of shorter irradiations must be given at longer intervals.

In consequence of this long-continued irritation, the papilla becomes incapable of producing a new hair. This is the method of *Schiff* and *Freund*.

Supposing however, that we can calculate and regulate the exact dose, are we certain of being able to produce atrophy of the papilla without a corresponding atrophy of the skin? It is well known that the hair follicle is more sensitive than the skin, but it is doubtful if there is sufficient difference in

this respect to enable us to destroy the one without affecting the other.

Schiff and *Freund* indeed assure us that a permanent cure may be effected without the production of cicatrices, but this may involve a course of treatment extending over years. Our own experience and that of many others is not even as encouraging as this. It is easy to produce an epilation, but the hairs invariably grow again, and it is fortunate if no accidental dermatitis or pigmentation occurs in the course of the continued alternations of epilation and regrowth. One case which we have had under treatment for more than a year is not yet cured. It is true that at each return the hairs are smaller, thinner, finer, and paler in colour; still, they recur again and again, to the despair of both patient and doctor.

In the treatment of hypertrichosis then, radiotherapy has not fulfilled its promise. In the present state of our knowledge we are not in a position to produce a permanent alopecia with any degree of certainty, and in certain persons of great sensibility there is danger of producing permanent cutaneous lesions which are more disfiguring than the hypertrichosis itself.

Whereas the coarser hairs fall out with great facility after irradiation, the same cannot be said of the fine, silky down which sometimes covers the face. This is most difficult to remove. At one time we had under our care a brunette who had a few dark-coloured hairs on the chin, which she imagined were disfiguring. We gave a dose of 4 H. to 5 H., enough in most cases to induce a complete alopecia. Instead of this a slight erythema occurred, followed by hyperpigmentation. In the course of one or two months this disappeared, but the hairs remained totally unaffected

In the treatment of sycosis of the beard, it has often happened that we have set up a slight dermatitis following a normal dose of the rays. Instead of the total alopecia which we feared, the whole beard has grown again uniformly without our being able to distinguish the localities where dermatitis had occurred.

Sabouraud says that all degrees of radiodermatitis are followed by alopecia of the scalp, but this is in no wise true of other regions of the body which are covered with hair.

In cases of alopecia areata, for instance, the X-rays are often used to stimulate the regrowth of the hair. The dose is a very small one, in order to produce stimulation rather than atrophy of

the hair papilla. It cannot be denied that good results frequently follow this mode of treatment.

If all the above facts are taken into consideration, it will be seen how difficult and complicated is the treatment of hypertrichosis by means of the X-rays. If the dose is too small, we run the risk of increasing the deformity by stimulating the growth of hair, whereas if the quantity of rays is too great, we may produce permanent disfigurement.

Moreover, when we consider the imperfection of the instruments of measurement at our disposal, we can well understand the difficulty, if not the impossibility, of satisfactorily treating this affection.

Apart from *Schiff* and *Freund*, most authorities, and among them *Béclère*, *Ehrmann* and *Kienböck*, are no great advocates of the treatment, and consider that radiotherapy is far from replacing electrolysis in the treatment of hypertrichosis.

In our opinion radiotherapy should be employed only in severe cases. It would be indicated in female patients who came to us with long, thick, disfiguring beards, since in these cases a slight degree of atrophy of the skin is less objectionable than the original affection. It might also be tried where there is a growth of thick, dark-coloured down over the surface of the face, since in these cases treatment by electrolysis is impracticable.

The following is the technique in the treatment of hypertrichosis, which, in our hands, has given the least unsatisfactory results:

The rays should be of moderate penetration, about No. 5 on Benoist's radiochromometer. With the focus-tube which we employ, the equivalent spark is $2\frac{1}{2}$ centimetres in length.

The distance of the tube should be 6 inches, thus enabling us to give a uniform irradiation over a surface 3 inches in diameter. In treating the various curves and angles of the face, the surface must be divided into a number of small areas, each of which may be treated as an approximately plane surface. A lead shield should be used to protect the parts which are not to be acted upon. The shield should be continually shifted, in order to avoid a hard line of demarcation between the part which has been rayed and that which has been shaded.

The quantity required for epilation is 3 H. or 4 H. for each separate area exposed to the rays, but this dose requires modification according to the sensitiveness of the skin—on the lips, for

example—and also according to the complexion of the patient, brunettes requiring less than blondes.

The full dose may be given at one sitting, or divided among several successive exposures. Generally only a slight degree of erythema supervenes, or there may be no visible reaction if the dose has not exceeded 3 H. Twelve or fifteen days after the termination of the treatment the hairs begin to fall out. The epilation that results is usually complete, but in certain cases it is only partial.

When all traces of reaction have disappeared—*i.e.*, thirty to forty days after the first séance—a new exposure of the same duration is made.

In this manner, by slow degrees, complete epilation results. To prevent the regrowth of air, a short exposure of five to ten minutes must be given about every two months, the quantity absorbed each time being about 2 H. By this means we may hope to obtain a permanent alopecia after treatment for two years. It must be remembered that the whole course of treatment is beset with dangers, and that after a year's treatment an atrophic condition of the skin is apt to make its appearance.

Radiotherapy is much more advantageously applied to a circumscribed hypertrichosis of limited area, or to a case of nævus pilosus. According to the severity of the lesion, the dose will vary from 4 H. to 5 H., which may be absorbed at a single sitting. After an interval of ten to twenty days, a more or less violent erythema appears, accompanied by a certain amount of œdematous infiltration of the skin. The hairs begin to fall out, and a total alopecia results in the course of a few days, the bald skin soon regaining its normal appearance. The regrowth of hair begins to appear after six or eight weeks, and it is then treated by a short irradiation of 2 H. to 3 H. After the treatment has continued for six to eight months the new hairs when they appear are atrophied, small, and blanched. After one or two years the region which has been treated remains perfectly bald, but at this date the special late atrophy we have already described may put in its appearance.

In these circumscribed cases the results may be equally imperfect with those of general hypertrichosis; but as the primary lesion—a hairy nævus, for example—is very disfiguring, a localized cutaneous atrophy of limited extent is of comparative unimportance.

We will merely give details of one case:

Mme. J. T., aged thirty-five, has suffered for two years from hypertrichosis of the face. There is a growth of hair on the chin, on the cheeks, and on the upper lip. The case has been treated by depilatories without success. There is a certain amount of acne.

From May 26, 1903, to March, 1904, she has had seventeen séances, with an average dose of 3 H. to 4 H. Usually after each séance the hairs fell out, but the regrowth was very rapid. Now and again a somewhat pronounced erythema occurred, but this was not followed by any more serious reaction. The concomitant acne was improved. By degrees the hairs in each new crop became fewer, and isolated patches became permanently bald. Even after this prolonged treatment the case is not completely cured.

Tricophytes.

In the treatment of hypertrichosis, it is desired to obtain a permanent alopecia of a region normally covered with hair; but there is no diseased condition, and the treatment is only justified from an æsthetic point of view.

The case is far otherwise when we come to consider the treatment of tinea. The hairs themselves are diseased, and invaded up to their very roots by parasitic colonies, which must all be destroyed before a cure is possible.

The usual treatment is by the application of some form of antiseptic. *Sabouraud* wrote some seven years ago: 'Not only is there no known cure for tinea tonsurans, but I think I am justified in saying there never will be a cure of this disease by the use of antisepsis. We may vary at will the chemical nature of the application we employ, but this will in no way alter their power of penetration. They may be solid, liquid, or gaseous, but none of them are able to overcome the physical obstacle to their use. The root of the hair is inaccessible to external antiseptics.'

What *Sabouraud* said of tinea tonsurans is equally true of favus. In this latter disease, however, there is a mode of cure which is entirely mechanical—viz., epilation of the diseased hairs by the use of tweezers.

In the case of tinea tonsurans, however, the hair is brittle, and cannot be entirely epilated by mechanical means. Instead of coming out, it breaks at the most diseased part, and the root which remains behind contains spores in abundance. The broken hair grows, the parasite increases, and the disease continues to spread.

As *Sabouraud*, from whose article on 'Radiotherapy in the Treatment of Tinea' we quote, says, the only possible solution of the problem is the discovery of an agent capable of suspending for a time the function of the hair-producing papilla.

In order to obtain this, *Sabouraud* employed a special toxin. Unfortunately the alopecia which it produced spread, and was not confined to the spot which was inoculated.

By the use of acetate of thallium he was able to obtain a perfect alopecia, but the poisonous effects of the salt obliged him to discontinue its use.

The discovery of the Roentgen rays introduced a complete change in the treatment of all these diseases.

By suitable irradiation of the diseased surface, more or less complete epilation can be produced, followed by a temporary arrest in the production of hairs. We thus obtain a complete clearance of the foci of infection, since the hairs which afforded a nidus for the parasite have been entirely expelled.

We must be careful, however, not to produce permanent alopecia, and the intensity of exposure must be well controlled so as to avoid this. The regrowth of the hair is one of the conditions of a successful result. The new hairs will be healthy if the follicle has previously been thoroughly cleared of all pathogenetic germs.

These considerations show the real value of the new treatment. Alopecia can readily be produced at will by the action of the X-rays. The only difficulty has been to render this alopecia permanent. In the treatment of tinea we only require a temporary epilation, and in this the X-rays are a most valuable auxiliary.

It would be difficult to give even a very incomplete history of the progress of the treatment. Most practitioners of radiotherapy have had more or less successful results.

As early as 1896 *Freund* treated a case of tinea with the rays, and in 1900 at the Congress of Paris *Schiff* asserted that radiotherapy was the treatment of the future for cases of favus. Since that date numerous cases have been treated in Germany, in England, and in America. In this connection we may mention the names of *Ziemmsen*, *Kienböck*, *Albers-Schönberg*, *Hahn*, *Grouven*, *Lion*, *Norman Walker*, *Scholtz*, *Boczar*, *Bukofsky*, *Socoloff*, *Pusey*, and others.

In Paris the first attempts at epilation were made by *Oudin* and

Barthélemy. Their experiments were first made on the normal hair of the pubis. Subsequently, *Gaston, Vieira,* and *Nicolau* presented to the Société de Dermatologie reports of cases of tinea cured by radiotherapy.

For three years, in collaboration with *Dr. Bisserié,* we have been in the habit of thus treating all cases of tinea which come to *Dr. Brocq's* consultations at the Broca Hospital. For the last year we have followed a method which enables us to obtain a temporary alopecia, followed by complete cure in almost every case.

In the course of 1903 *Dr. Sabouraud* sent us his assistant, *H. Noiré,* to whom we showed our technique and its results.

Following this method, *Sabouraud* obtains most excellent results, and the number of cases he has treated has enabled him to fix with great precision the rules for the treatment of tinea by the X-rays. He has reported his results in the *Annals of the Pasteur Institute* for January, 1904.

The fragility of the hairs affected with tinea renders it impossible to epilate these cases satisfactorily with forceps. The X-rays, by arresting the growth of the hair papilla, afford a perfect means of epilation.

In tinea tonsurans of the scalp the existence of the lesion is chiefly noticeable by the loss of hair, due to the diseased hairs being broken off short at the surface of the skin. This appearance is sometimes accompanied by a few squamæ and crusts on the affected region, the local inflammatory reaction not being of any great intensity.

Kienböck considers a dose of 5 to 7 Holzknecht units is necessary and sufficient for complete epilation, the rays employed being of small penetrating power. It is true that *Schiff* and *Freund* advocated the use of hard tubes, but under these conditions forty to fifty applications were frequently required before a cure was effected.

Sabouraud has recently given the following therapeutic formula: 'In order to cure a patch of tinea, an exposure should be given with a Villard focus-tube at a distance of 6 inches from the skin, with rays corresponding to No. 4 of Benoist's radiochromometer, and the total quantity absorbed should be 4 H. or 5 H. in Holzknecht units.' By this means we obtain the exact result required—an epilation pure and simple, without any complication or dermatitis.

Our first attempts were made in conjunction with *Dr. Bisserié*, under the influence of the ideas inculcated by *Schiff* and *Freund* before the introduction of instruments for measuring the dose. We gave short séances frequently repeated, and our results were consequently irregular and unsatisfactory. As soon as we were able to make use of instruments of precision, we began to give massive doses. We agree with *Sabouraud* that a séance of twenty-five minutes is necessary and sufficient, since an exposure of that duration was required to cause the absorption of the required dose with the installation at our disposal.

Let us take for an example the case of a patient affected with a patch of tinea tonsurans on the vertex. We place the patient in a sitting position, and after having protected the surrounding parts, we proceed to irradiate the diseased area, including a margin of healthy skin at least a centimetre broad.

In the early days of radiotherapy the protection consisted of a leaden shield, pierced by an aperture rather larger than the lesion to be treated. This was heavy, awkward, and difficult to keep in place. We now employ a localizer of our own design, with a tube of length and diameter adapted to the size of the patch we are treating. *Sabouraud* employs a similar appliance made by Drault.

The rays are of a penetration corresponding to No. 5 on Benoist's scale. The equivalent spark is 2 centimetres in length with the static machine, and 2½ centimetres when the other installation driven by a Ruhmkorff coil is used.

The whole dose of 5 H. is absorbed by the diseased area in one séance, or at the most in two consecutive séances. This will require an exposure of fifteen to thirty-five minutes, according to the distance of the tube.

No apparent modification of the scalp follows this exposure. From the sixth to the tenth day after the application a hardly perceptible erythema may appear. Some observers consider that this occurs in every case, but that it is often overlooked. After some days—three or four, according to *Sabouraud*—the erythema disappears, and is followed by pigmentation of so slight a nature that it is only observed with great difficulty. From the fifteenth to the twentieth day after exposure, the hairs begin to be shed over the whole of the irradiated area, coming out spontaneously, or with very slight traction. According to some observers, they become blanched before falling out, and although we have never

observed this, we have noticed that they occasionally appear atrophied, and that all the hairs of the irradiated area appear grayer and duller than ordinary. They are burned, say the patients—withered like plants that have been scorched by the sun.

In the course of a few days the epilation is completed. *Sabouraud* advises a daily washing with soap, followed by slight friction with a weak solution of iodine, in order to facilitate the process of epilation and to insure asepsis of the bared surface.

During the production of this temporary alopecia, the hairs fall out in consequence of a withering of the papilla, whose function of hair production is thus temporarily arrested. The diseased hair is expelled from the hair follicle long before a new hair is produced.

Sabouraud thus describes the process: 'Even when the new hair grows up soon after the expulsion of the old one, a certain thickness of the epidermis is interposed between the new and the old hair. Thus any parasitic growth in the diseased hair is prevented from contaminating the new hair which grows up underneath it, the diseased and dead hair being meanwhile expelled by ordinary physiological means. In a case of tinea, the diseased hairs, like those of the healthy skin, are eliminated by a temporary atrophy of the papillæ. They shrink little by little, separate from their papillæ, and are finally expelled.'

This then, is the method by which a cure is effected. It is a purely mechanical action, insuring the destruction of the trichophyton. The X-rays do not exercise any sort of bactericidal action. As we have already explained, no such action is possible under ordinary therapeutic conditions. The trichophyton is not affected in its vitality, but the hair in which it is domiciled is expelled. After epilation by the X-rays, the very last débris of diseased hair are infiltrated with living parasitic growth, and *Sabouraud* found that the cultures made from these débris were invariably fertile.

This explains why the occurrence of reinoculation is so frequent. 'The diseased hairs which fall out,' says *Sabouraud*, 'are admirable spore-bearers. This proves the absolute necessity of a constant and careful antisepsis of the scalp, from the moment of the first exposure till the epilation is complete and the diseased area completely bald.'

Napthol soap may be recommended for this purpose, or, as is

done at St. Louis, daily frictions of the whole scalp with tincture of iodine diluted with five times its volume of spirit may be employed.

If the treatment is successful, the regrowth begins seven or eight weeks after depilation—*i.e.*, about ten weeks after the first exposure. The regrowth is however very slow. We have never failed to obtain the regrowth of the hair, but in some cases it has been delayed for twelve or thirteen weeks after epilation. In normal cases, according to *Sabouraud*, it should be complete two months after its commencement.

This slow growth is not in reality a disadvantage, since it gives time for the diseased hair to be expelled long before the new hairs appear which therefore, run less risk of infection.

The rapidity of the regrowth depends in part on the sensitiveness of the subject and of the region affected, but still more on the quantity of X-rays absorbed. The greater the reaction, the slower the regrowth.

This leads us to the consideration of the various complications which may occur in the treatment of these affections. We have fixed 5 H. as the medium dose for the scalp of an adult. In a child 4 H., or even less, will be amply sufficient. Let us repeat that the time of exposure is of no importance, but only the quantity of rays absorbed. We need to take into account individual variations in susceptibility. We have met with patients in whom depilation has been incomplete even after the absorption of 6 H., whereas in other cases a similar dose was followed by reaction occurring chiefly near the centre of the irradiated areas. This was followed by the appearance of a few pustules and scabs, which however soon disappeared under the application of a 2½ per cent. solution of iodine in glycerine.

When the disease is situated in the beard, it is necessary to proceed with great caution. A dose which would be readily borne by the scalp might set up a serious inflammation of the face, which will not however always give rise to alopecia.

We often notice in dermatological practice the immunity with which the scalp supports the action of irritants which would set up serious inflammatory reaction on the face.

If one may trust the observations of *Sabouraud*, the oblique rays are more irritating to the epidermis, but have a feebler depilating power. 'The human scalp,' he says, 'and especially

that of infants, presents a convexity of considerable curvature. If now a localizer-tube of wide diameter is applied to such a surface, the oblique rays striking the skin near the margin of the cylinder are almost tangential to the surface. In this situation a traumatic folliculitis is apt to occur, which becomes infected by the staphylococci always present on the scalp. Some three weeks after the operation, we therefore find a circle of follicular pustules surrounding the depilated area.' This is not a serious complication, but somewhat tedious and usually avoidable.

The oblique rays are certainly not so active as a depilating agent. The intensity of action depends on two factors—the sine of the angle of incidence and the distance of the point of incidence from the source of the rays. There is no reason to suppose that the very oblique rays have any special irritative action, it being more likely that the staphylococcic infection is due to a local irritation set up by incomplete epilation, the dead hairs acting as foreign bodies.

It is advisable to obviate this complication as far as possible by reducing the area exposed at each sitting. *Sabouraud* recommends an external application containing sulphur. The following liniment may be applied daily by means of a brush:

Sulphur. præcipit.	15 grammes.
Alcohol 90 per cent....	15 ,,
Aqua dest.	ad 100 ,,

With a single patch of ringworm the treatment is quite easy. We irradiate the diseased patch, including a good margin of healthy skin, and a single application will produce an epilation of the whole of the affected hairs. In cases where there are several well-separated patches the treatment is equally simple. The problem, however, becomes much more complex when the whole scalp has to be epilated. This may be best done by dividing the surface of the scalp into a number of small areas. If it is desired to act on the whole of the vertex at once, it will be necessary to remove the tube to a greater distance, the time of exposure being increased in proportion to the square of the distance. This adds considerably to the length of the sitting, during which it is difficult to insure the immobility of the patient.

It is far better to irradiate successively a number of small contiguous areas. Here, however, a difficulty arises in making the

boundaries of adjacent areas coincide, without any interval or overlapping, when the edges would be irradiated either insufficiently or too much. In the one case the subsequent epilation will be incomplete, in the other it may give rise to dermatitis. *Sabouraud* finds a difficulty in fitting together the circular patches of epilation, which are apt to leave triangular areas between them. It is easy, however, to obviate this difficulty by employing shields with rectilinear openings. Much more convenient is the use of the localizer, when the lower aperture of the tube may be limited by a rectilinear diaphragm. In this case the areas irradiated at each séance would be smaller, but it would be much easier to fit them together. Exact localization and dosage are of great importance. If only a few diseased hairs escape the action of the rays, they will form foci of reinfection, and if the same area is irradiated a second time there is danger of dermatitis. On the other hand, if a second irradiation is too long delayed, dermatitis will not occur, but one risks the production of a permanent alopecia.

Sabouraud, in his interesting observations on this question, asserts that a permanent alopecia may result, even without the occurrence of erythema or radiodermatitis.

We should therefore be careful to limit the area of exposure with the greatest exactitude, to irradiate at one sitting with a suitable dose, and to avoid all retouching for a considerable period.

'Suppose,' says *Sabouraud*, 'that one has given an insufficient dose—say $3\frac{1}{2}$ H.—the epilation which follows will be incomplete, and a number of infected hairs will remain on the diseased patch, necessitating a new exposure. Suppose we give $4\frac{1}{2}$ H. on this occasion : the hairs which remain after the first irradiation will fall out, but many of those already shed will be destroyed and will not grow again.'

On two occasions, while treating ringworm, we have met with a curious appearance. After epilation, two distinct zones could be distinguished on the bald surface of the scalp. The central zone, corresponding to the original patch of tinea, was slightly pigmented, and of a brown colour, whereas the margin of the bald area corresponding to the healthy skin remained of a normal white colour. In neither case was there any appearance of reaction.

Let us now consider what is the value of this treatment. Is the success absolutely certain and the tinea invariably cured, or are there any restrictions to its employment?

Sabouraud asserts that the proportion of failures does not exceed 5 to 10 per cent. These are mostly attributable to three causes:

1. An insufficient epilation at certain points, which leaves a few diseased hairs *in situ.*

2. An oversight in the treatment, leaving one or more small islands untreated, an omission which is only observed after the rest of the head has been epilated.

3. Reinoculation during the course of treatment.

Dr. Auché in his report to the Medical and Chirurgical Society of Bordeaux in 1904 attributes his failures to similar causes.

This small percentage of failures is very encouraging. In the majority of cases a perfect cure follows a complete epilation of all the diseased hairs. The great difficulty is to produce this epilation with certainty, so as to make sure that no diseased hairs remain to form a foci of reinfection for the new growth.

In any case patients should be kept under careful observation. The regrowth of hair should be watched, and if that is healthy we may be assured that there will be no recurrence of the disease.

With all its difficulties, this method is a great advance on all those which have preceded it. It is rapid in its action and perfectly painless. It is the only method which insures a complete epilation, and it is much to be preferred to any other mode of treatment.

Radiotherapy enables us also to treat a greater number of patients. This is of importance in public institutions such as the École Lailler in Paris. Before the introduction of radiotherapy *Sabouraud* cured fifty-seven cases in a year. By the new treatment he obtained 134 successful results in a period of six months. Moreover, it is no longer necessary to keep the patients in hospital, as the daily treatment required is of the simplest description.

In conclusion, we may say that Roentgen's discovery, aided by a methodical system of dosage, has completely revolutionized the treatment of ringworm.

We need not enter into a consideration of the cases of ringworm, six in number, which we have treated during the present year, as they possess no special points of interest.

The following is a résumé of the technique to be employed: A patch of tinea may usually be epilated by the absorption of

5 H. by every portion of the diseased area, with rays corresponding to No. 4 or No. 5 of Benoist's scale. The epilation is usually followed by the complete cure of the disease.

Favus.

Almost all that we have said of the treatment of tinea tonsurans applies equally to favus. In the latter disease the hairs do not become brittle, and consequently can be more easily removed by the usual means of epilation.

At first sight radiotherapy would not seem to offer any great advantage over the older methods, for the only effect of the rays is to produce epilation. Although some authorities assert that the X-rays exercise a modifying action on the cutaneous lesion, this has never been demonstrated. As far as regards any possible bactericidal action, it may be put out of the question, for as we know, the Roentgen rays in therapeutic doses are totally incapable of modifying the parasitic growth.

Favus is generally disseminated, and only rarely limited to any particular portion of the scalp. *Freund*, who has had a large experience in this disease, recommends the complete epilation of the scalp, as the only means of avoiding recurrence. The following is his method: 'We begin by irradiating the vertex, subsequently attacking the sides of the head, and finally the occipital region. The anticathode should be 10 to 12 inches from the surface, so that as large an area as possible may be irradiated at a single sitting.' In his opinion the irradiation for the cure of favus should be more intense than is necessary in the treatment of other diseases of the scalp.

After three weeks' treatment by *Freund's* method, the hairs begin to fall out, either spontaneously or with very slight traction. On separating the remaining hairs, a slight erythematous blush may be seen on the surface of the scalp. During another fortnight the alopecia gradually increases till it becomes complete. If there are any favus depressions on the irradiated area, they exfoliate, discharge, and heal in the course of ten days or so. After a time the surface appears smooth, bald, and shining like a billiard-ball.

The hair begins to grow again from six to eight weeks after the termination of the treatment. A fine down first appears, which

grows stronger little by little until it assumes the appearance of the adult hairs.

In the majority of cases the regrowth is perfectly healthy, and the case may be considered cured if there is no return of the disease within the next ten weeks.

In rare cases a slight recurrence may necessitate another short series of irradiations.

When relapses occur, must we regard them as due to imperfect epilation, to infection of the neighbouring parts, or to the presence of the parasitic growth in the follicles?

Török and *Schein* consider that the recurrence is caused not so much by spores lurking in the follicles as by a reinfection from without. They agree with *Freund* in recommending the complete epilation of the whole scalp.

The surface of the scalp must also be kept in a thoroughly aseptic condition. This may be done by the use of the diluted tincture of iodine, as recommended by *Sabouraud* in cases of tinea. It is perhaps preferable to use carbolic acid, which has been found by *Caldcrone* to be most destructive to the fungus of favus. A useful application is the preparation of carbolic acid in lanoline, recommended by *Freund*.

The scalp should be massaged night and morning, and the ointment well rubbed in to all the bare spots. This treatment should, however, not be commenced till all signs of reaction have disappeared.

In this way *Freund* has cured several obstinate cases in the course of a few weeks. Some of his cases have not recurred after the lapse of two or three years. If there is some recurrence, in spite of the carbolized applications, we must give a second series of irradiations, proceeding with great caution, as any violent reaction will lead to permanent alopecia.

In summing up the advantages of this method, *Freund* considers that it acts principally by depilation, but that in addition the rays exercise a stimulating action on the hair follicles, modifying their nutrition, and causing destruction of the cells which harbour the parasite. This is only a hypothesis however, since no precise histological observations have as yet been made.

In 1892 *Gaston* and *Vieira* epilated the scalp of a patient suffering from favus, with successful results.

Scholtz has alsotreated a few cases of favus. He denies any

bactericidal action of the rays, but admits a possible favourable influence on the concomitant cutaneous lesions, and avoids any inflammatory reaction in the course of epilation. He has, however, never met with a case of permanent cure by the Roentgen rays. 'We have repeated our experiments again and again,' he says, 'and we have always found diseased hairs among the new growth even after a total depilation of the scalp.' He recommends a supplementary course of treatment of a very energetic character with carbolic or pyrogallic preparations, chrysophanic acid or chrysarobin. Unfortunately, even with these precautions there is often a return of the disease, and it is necessary to make another series of exposures in order to hinder the regrowth of diseased hair.

Holzknecht recommends the epilation of the whole scalp, since if any portion is left untreated there is sure to be a relapse. He prescribes a dose of 4 H. or 5 H. at a single sitting. He finds a most marked reaction over the whole of the inflamed areas, characterized by irritation of the cup-like depressions, erosion, and desquamation, complete resolution occurring in three weeks after the commencement of the treatment.

Kienböck describes his method thus:

'We epilate the entire scalp in a single sitting. The whole head is divided into six areas, which are irradiated successively, for a period of five to eight minutes each, with an absorption of 4 H. or 5 H. After a latency of ten or twelve days the hairs begin to fall out, the patches of mycosis and of eczema begin to inflame, and the reaction, although occasionally limited to simple swelling, usually attains to the second or third degree of intensity, with erosion and exudation. After six weeks the hairs begin to reappear, those parts which have become atrophied by the mycosis remaining bald. After three months the head is covered with healthy normal-coloured hair, and there is no return of the disease.

'In our opinion radiotherapy represents by far the best treatment for mycosis favosa. In the more serious cases it is the only treatment, and the disease may be cured speedily and painlessly by a single exposure.'

At St. Louis, *Sabouraud* employs the same treatment for favus as for tinea tonsurans. At the École Lailler he treats cases of tinea and of favus side by side. 'Both diseases,' he says, 'are amenable to the same treatment, which lasts a few weeks only, in place of the years required under the old method.'

Pusey and others do not attach much value to this method, and consider that the results do not answer to our expectations.

Williams, *Norman Walker*, *Lion*, *Grouven*, *Hahn*, *Neumann*, *Ziemssen*, *Albers-Schönberg*, *Spiegler*, *Boczar*, *Bukofsky*, and others have obtained more or less satisfactory results.

In cases of tinea tonsurans the treatment is facilitated in proportion to the limited extent of the lesion, and the cure is much more certain when the disease is localized.

Favus, on the other hand, invades a large part of the scalp, and to obtain a successful result it is necessary to epilate the whole of the scalp, and this requires both time and patience.

In tinea moreover, the parasite is localized in the hair itself, and it is natural to expect that its total expulsion will cure the disease. In favus, on the other hand, the achorion occupies not only the hair, but the neighbourhood of the follicle, and sometimes the follicle itself. Thus epilation alone is often insufficient to ensure a complete cure. Antiseptic treatment is required to supplement the epilation, since the X-rays themselves are not bactericidal under therapeutic conditions.

This invasion of the follicle by the fungoid growth explains why the result is the more certain the longer the duration of the alopecia. The longer the alopecia the less likely is the new hair to encounter a pathological germ during its growth, in which case a recrudescence of the disease would be inevitable.

In spite of these drawbacks radiotherapy is the best treatment for favus, and especially for those severe cases where other means have proved ineffectual.

Besides their depilatory action, X-rays have a beneficial effect on the favus cups and the concomitant dermatoses. A few days after irradiation the irritation is accentuated, new depressions and crusts appear in situations hitherto apparently healthy, and sometimes even slight erosion occurs. Soon, however, all this calms down, the crusts fall off, and the scalp becomes bald, with no apparent lesion.

If the exposure has been of proper intensity, there is a normal regrowth of hair, as in cases of tinea tonsurans, with this difference however, that there is no return of hair in the cicatrices of the primary lesion.

The dose necessary for epilation in a case of favus is the same as for a case of ringworm—viz., 5 H.

We have ourselves had a completely successful result in a case of favus. In this instance the lesion was limited in extent, and epilation was followed by a perfectly healthy growth of hair. Some cases still under treatment have been greatly improved, and we expect to get in these also a completely favourable result.

Sycosis and Folliculitis of the Beard.

Schiff and *Freund* were the first to use radiotherapy in the treatment of sycosis. They were led to employ it on the supposition that a cure would follow total epilation, since they considered that the hairs themselves acted as irritants. By removing them they hoped to eliminate the cause of the inflammation, which extended to the walls of the glands, the skin and the hair follicles.

In practice *Freund* considers that there are two principal factors —the character of the disease, and the extrinsic condition of the patient.

When the lesion is widespread, with purulent pockets under the skin, only a small number of exposures should be given, using a hard tube. These are sufficient to induce a notable amelioration. The infiltration diminishes, the pustules dry up, the pruritus and tension of the skin are diminished, and the surface of the skin assumes a deep-red colour.

The lesion may assume another form, consisting of small red pimples around the hair, with a few pustules here and there, as in the folliculitis barbæ, or acne pilaris of Besnier. In this case the patient should if possible shave off his beard and remain without one for some time. For this purpose a series of irradiations is given, so as to procure a complete alopecia, which is maintained if necessary by a few supplementary exposures. As the skin is much more sensitive than usual, it is advisable to act with caution in order to avoid reaction.

On the subsidence of inflammatory reactive symptoms, the depilated surface should be treated with a 15 per cent. sulphur ointment.

In 1901 *Freund* had already treated seventeen cases of sycosis. Five of these were completely cured by a single series of exposures; in five others a second series was required; in one case only was a fourth series found necessary.

Gastou, *Vieira*, and *Nicolau* obtained complete epilation after

eleven séances. In no instance did excessive reaction take place. The cases were quickly cured, but there was often a recurrence after some time, which usually yielded to a second series of irradiations.

Scholtz has seen cases of slight sycosis permanently cured by the X-rays. In severe and inveterate cases there was generally a recurrence of the disease when the new hairs began to grow. A long course of treatment is indispensable, and after some weeks' interval a second series of exposures is required to delay the regrowth, or even in some cases to permanently destroy it.

François of Valenciennes cured a case of sycosis with three exposures, with a duration of ten minutes on each occasion. The focus-tube was placed at a distance of 10 inches, and was driven by a static machine.

Kienböck proceeds in the following manner: When the whole of the beard is affected, the irradiation is given successively over four distinct areas—the right cheek, the left cheek, the lips, and the chin. The tube should not be placed too close, as this would produce unequal epilation, and perhaps some permanent alopecia of the beard in places.

The normal dose of 3 H. to 5 H. is given, and the mucous membrane of the lips and the bare portions of the face should be carefully covered by a metal shield. After a latent period of seven days the epilation commences, the inflammatory symptoms increase, the small abscesses around the hairs are evacuated, and after a time the skin heals completely. When the hairs begin to grow again, about six weeks later, the beard should be shaved, and this should be continued for many months. The results are least favourable in those cases where an irritation is kept up by some external cause, as, for instance, a chronic rhinitis.

Holzknecht advises the irradiation of the whole of the affected area which is covered with hair. He recommends a dose of 3 H. to 5 H., according to the case, and tells the patient not to shave for a time. At the end of a week the irradiated area becomes more inflamed, the existing pustules rupture, and new ones appear. A complete alopecia follows, after which the skin regains its normal aspect. Regrowth begins to appear after about two months, but the patient should continue to shave his beard for a year or more. Relapses often occur, especially if the inflammation is kept up by extrinsic rhinitis producing sycosis of the moustache.

Williams, *Lancashire*, *Grouven*, *Gassmann* and *Schenkel*, *Spiegler*, *Lion*, and others, have had successful results with this method. *Pusey* speaks very highly of it.

In his work on radiotherapy *Ullmann* considers that this method is indicated when the sycosis is superficial; but if there are subcutaneous abscesses, the penetration of the rays is insufficient.

As in favus, the principal effect of the X-rays on sycosis is due to its depilatory action. The method is preferable to depilation by means of forceps, both on account of the rapidity of its action and its freedom from pain. In addition to their depilating action, the X-rays have an influence on the skin in consequence of the inflammatory reaction which they set up. In many cases moderate irritation exercises a beneficial effect, and the irradiated pustules dry up and disappear. Thus, when the lesion is slight, the disease located around the hairs, and the infiltration limited in amount, radiotherapy is a valuable means of treatment.

It may be employed even when the follicles are attacked, and the dermis is more or less thickened. It will not, however, enable us to cure cases where deep-seated purulent abscesses exist, with considerable infiltration of the skin.

Moreover, these lesions are exceedingly irritable, and the possibility of serious dermatitis should render the practitioner very cautious in treating such cases with X-rays, and make him very reserved in his prognosis.

It is well not to demand of radiotherapeutic treatment more than it can perform. It is a depilating agent; it is, if you will, a cicatrizing agent and an absorbing agent, destructive to staphylococcic growth; but it will not cure extensive purulent collections. No one has ever claimed for the X-rays the faculty of absorbing an abscess, or taking the place of the bistoury.

At the Broca Hospital we have treated several cases of sycosis and folliculitis of the beard, some of them affecting the whole of the hairy surface, while others were localized on the cheeks or upper lip. The results were, on the whole, favourable, and certainly more rapid than by ordinary methods. In all these cases the integument was infiltrated, but there were no great purulent accumulations, although most of the follicles were affected. In one case the disease had already continued for a year, and the patient complained of intolerable itching and smarting. The irradiations were so proportioned as to produce complete epilation without der-

matitis. The dose varied from 3 H. to 5 H., according to the state of the skin and the situation of the lesions.

The epilation was affected more easily where the lesions were most marked. In some instances a second application was necessary after fifteen or twenty days, in order to complete the epilation. Usually the hairs begin to fall out in from twelve to fifteen days, and this may be accompanied by erythema, varying in degree according to the intensity of irradiation. As soon as the hairs fall out, and sometimes even before this, the pustules are altered in appearance. The scabs fall off, and there may be some slight weeping. The discharging purulent surface drys up and heals, and the skin regains its normal state, with the exception of some brown coloration, and a marbled appearance which is usually more or less apparent. At the same time, all symptoms of pain and itching, which had diminished from the very commencement of the treatment, entirely disappear. At this stage it is useful to prescribe sulphur or ichthyol applications, and in obstinate cases a new exposure of 2 H. or 3 H. may be given to retard the new growth. Occasionally fresh foci of disease make their appearance, especially if the alopecia has been of too short a duration, and these will require a second course of irradiation. Recurrence is common under all varieties of treatment. Even epilation by means of forceps, which is both tedious and painful, does not entirely obviate it.

Dermatitis occurs with great facility in these cases, and is to be studiously avoided. The tissues are badly nourished, infiltrated, and infected, and hence are much less resistant to injury of all kinds. Under a full dose, and sometimes even with a moderate dose of the X-rays, the skin breaks down, the epidermis peels off, leaving a large weeping surface, red in some places, yellow in others, covered with crusts, and bathed with a serous or purulent discharge. In spite of this, a few hairs will often remain attached to the skin as a proof that the epilating dose has not been exceeded. This condition is embarrassing, but is not followed by any permanent injury. The process of healing sets in rapidly, and is completed without visible scarring. It is often difficult to determine from the aspect of the patient whether the reaction is a true radiodermatitis or a mere exaggeration of the pre-existing inflammation.

We should take every precaution to avoid this dermatitis, as it

is apt to be followed by patches of permanent alopecia, which are very disfiguring and a great annoyance to the patient.

If there is much reaction, we must wait till this has completely abated before proceeding with the treatment.

According to *Freund*, radiotherapy may also be employed with success in the treatment of chronic sycosis, with nodular infiltration. The X-rays produce an epilation which is followed by a considerable diminution and flattening of the nodules. The results we have obtained in the treatment of keloid confirms *Freund's* observations.

We cannot say much as to the question of recurrence, which is not infrequent, although a second series of exposure is generally sufficient to cure it. In cases of persistent recurrence it may become necessary to produce a permanent alopecia. This, however, is a proceeding which requires the exercise of the greatest care and patience.

Freund considers that the beneficial effect is entirely due to the suppression of the hairs by the depilating action of the rays. Others have imagined that the X-rays may in some way facilitate the entrance of medicaments into the follicles. *Freund* however does not agree with this view. The mechanism of the cure, in his opinion, is, ' that the epilation removes the irritation of the foreign body which keeps up the inflammation of the follicle.' Herein lies the advantage of radiotherapy, which keeps up an alopecia of longer duration than that obtained by ordinary epilation.

In conclusion, we may say that in the treatment of sycosis the X-rays produce a complete and painless epilation. They also exercise a beneficial action on the cutaneous lesions due to staphylococcic infection, either by direct influence or by suppressing the hair which acts the part of a foreign body.

Case I.—M. L., aged twenty-five. Sycosis vulgaris of the beard of two years' duration, involving the cheeks and chin. The patient complains of terrible sensations of burning and itching. The skin is red and covered with crusts, each hair being sheathed by a tiny abscess. There is general infiltration of the skin over the whole diseased surface. The patient has been subjected to various methods of treatment without result.

January 18, 1904.—Exposure of 5 H. on the right cheek. Quality of rays No. 4 or No. 5.

February 3.—The epilation commenced on the side which has been treated. The skin is red ; the folliculitis continues.

An exposure of 5 H. on the left cheek.

February 17.—The epilation is complete on the right cheek. The pain and itching have disappeared completely. The infiltration of the skin has diminished; the pustules have disappeared, leaving only a few crusts; the whole skin is deep red, and has a marbled appearance. Epilation has commenced on the left cheek.

An irradiation of 4 H. to 5 H. is given to the chin.

From February 18 *to April* 27.—Six séances have been given, with an exposure of 4 H. to 5 H., on each of the affected areas. Epilation is completed over the whole surface. There has been a sharp reaction on the chin over a small area, where numerous crusts were to be seen before the commencement of the treatment. Here slight ulceration occurred, and the wound became impetiginous, but this has speedily subsided.

May 11.—There is no reaction except on the chin, which is copper-coloured. The healing is almost completed without any scarring. Everywhere else the cure is complete. The patient is much pleased with the result.

May 30.—The patient is well. On the right side the hairs are beginning to grow, the regrowth being perfectly healthy. All morbid appearance has completely disappeared.

In July, when the patient was again examined, there were no traces of the disease left.

Case II.—M. B., aged twenty-six. Sycosis of the beard of four years' duration, with alternate periods of amelioration and aggravation. At the present time the lesion is exacerbated, and the itching is violent.

From March 24 to April 26, 1904, the patient had four séances, with a dose of 4 H. to 5 H. on each diseased area. The rays were No. 4 or No. 5 on Benoist's scale.

On one cheek the reaction was very marked. The epilation is complete all over the irradiated areas. The itching has abated. The skin has regained a normal appearance, though still coloured deep red.

At the beginning of June the patient was seen again. The hair had begun to grow at certain points. The growth was healthy, and the skin of the face had regained its normal colour. The patient was cured.

Blepharitis.

Whilst treating cases of sycosis, eczema, or acne of the face, *Freund* noticed on several occasions that concomitant blepharitis was speedily cured

In collaboration with *Schiff*, he published the first case of this affection cured by X-rays. It was a case of blepharitis occurring in a patient who was under treatment for sycosis. He has since treated three cases of the disorder. Whether the lesion be a simple inflammatory ulceration or a squamous eruption of the edges of the eyelids, it is speedily cured by a few exposures with a hard tube. The crusts are detached, the excoriations are cicatrized, and the skin becomes normal without the shedding of the

eyelashes. No application of medicaments is required, and the catarrhal conjunctivitis rapidly improves as soon as the blepharitis is cured.

We have not as yet had occasion to treat a case of blepharitis by this means. We should be inclined to give a smaller dose of 3 II. only on Holzknecht's scale, and to employ rays of slight penetrative power.

The cornea is but little sensitive to the action of the X-rays; this should favour successful treatment. It seems remarkable that in *Freund's* case resolution should have occurred without the shedding of the eyelashes.

Even if these had fallen out, it would not have mattered, as their regrowth is almost certain, and a temporary alopecia might have even hastened the cure of the blepharitis.

Trichorrhexia Nodosa.

Freund treated an obstinate case of trichorrhexia nodosa of many years' duration by means of the X-rays. He gave twelve séances of seven to ten minutes each, which were followed by a slight erythema and a partial shedding of the diseased hairs. When the hairs began to grow again the cure was complete.

Probably in this disease the X-rays act merely as a depilating agent. *Sabouraud* has shown that in many cases of trichorrhexia the disease is kept up by the use of soap, and that a cure results from the mere suppression of its use.

2. Diseases in which the X-Rays have a Stimulating Effect on the Hair.

Alopecia.

On November 2, 1900, *Kienböck* presented to the Medical Society of Vienna the first successful case of alopecia treated by X-rays. The case was that of a man, twenty-six years of age, who had lost the whole of his hair three years before. The upper part of the head only had been treated with six applications of the X-rays each, of fifteen minutes' duration, the tube being placed at a distance of 8 inches from the skin. The yellowish down which covered the whole scalp rapidly fell out from the irradiated areas, and at the end of two months a normal growth succeeded. The

alopecia persisted on those parts of the head which had not been irradiated.

On December 7, 1900, *Holzknecht* published a similar case, which was cured by five applications of ten minutes' duration; the centre of the tube being at a distance of 8 inches from the skin. The success of his first attempt encouraged him to repeat the treatment in other cases. The results, although not uniformly successful, were on the whole encouraging.

He describes two distinct methods of treatment. Each patch may be treated separately, taking care to irradiate an area rather larger than that covering the lesion, and protecting the rest of the scalp by a lead mask. Or the whole of the scalp may be irradiated, without regard to the healthy regions.

Each of these methods is applicable to different conditions. If the lesions are confined to one or two patches of small extent, it is of course better to treat the patches exclusively. Even when the disease is widespread, but is surrounded by a margin of healthy hair, it is preferable to limit the exposure to the diseased patches. As the result of experiments made by *Holzknecht*, it was found that irradiations confined to the diseased surface were more efficacious. When, however, the number of patches is considerable, and we suspect the existence of latent foci of disease, the whole scalp must be attacked if the case is to be treated with any prospect of success.

In all his cases *Holzknecht*'s aim is not to exceed the first degree of inflammatory reaction, which is the production of simple hyperæmia.

For alopecia of the beard, from 3 H. to 4 H. should be given, and from 4 H. to 5 H. for alopecia areata of the scalp. Some cases are greatly ameliorated, but others prove refractory to all treatment. *Freund* obtained good results by following *Holzknecht*'s method. *Kienböck* says: 'In certain cases alopecia areata may be cured by radiotherapy. Each focus of disease should be irradiated in turn, and a normal exposure of 3 H. to 4 H. is in most cases sufficient. At the end of a fortnight the hair on the margins of the affected area is shed. After four to six weeks—*i.e.*, two to four weeks after the epilation—a growth of hair commences on the bald patch, and this is quickly followed by a regrowth of hair on the healthy margin surrounding the patch.

Radiotherapy has proved quite ineffectual in those severe cases in which the head is completely bald and smooth, without any

trace of lanugo, and where the eyebrows and beard are also affected.

Williams considers that X-rays are capable of stimulating the growth of hair. He reports the case of a patient who was rapidly losing his hair, and who insisted on being treated by the X-rays, although he was told that the remainder of his hair would probably fall out. A total alopecia resulted, but this was followed by an abundant new growth, and the final result was most satisfactory. In another case of alopecia areata, radiotherapy was attended with good results. No reaction occurred with the exception of a slight erythema.

Foreign authors report contradictory results. In spite of the fact that as long ago as 1901 *Holzknecht* formulated the rules for its employment, this mode of treatment for alopecia has made but little progress.

In his recent work *Ullmann* cites some instances of undoubted amelioration resulting from radiotherapeutic treatment.

When *Kienböck* made his first communication, *Kaposi* would not admit that the results were due to the action of X-rays. 'All modes of treatment,' said he, 'are successful, when they are adopted just before the occurrence of a spontaneous cure.' *Noble* pointed out that *Kienböck's* patient showed the clearest signs of the curative action of the rays. *Kienböck* also argued that it was impossible to deny this action, since the new growth was confined to the spot which had been irradiated, and the alopecia in the neighbouring areas had not been modified.

The demonstration in this case appears to be conclusive, and the fact that it does not accord with our preconceived notions does not in any degree diminish its value.

At first sight it may seem contradictory that the same agent will in one case cause the hair to fall out and in another case favour its regrowth. The contradiction, however, is only apparent, as the result depends on the amount of rays absorbed by the hair papilla, and the consequent inflammatory reaction. It is evident that if this factor is varied the result will be altered.

At first the beneficial effect of radiotherapy was attributed to a destructive action of the rays on the mycotic growth, which causes alopecia areata. *Freund* opposed this hypothesis.

To begin with, it has not been proved that the disease is invariably caused by a pathogenic micro-organism. Even if this is so,

it has been shown that the X-rays in therapeutic doses do not exercise a bactericidal effect. We agree with *Holzknecht*: 'The cure of these infectious processes cannot be due to the destructive action of the Roentgen rays, since the bactericidal dose is enormously greater than the curative dose.' It is probable that the true cause must be sought in the hyperæmic reaction. This is the view of *Schiff*, *Freund*, *Ehrmann*, and *Holzknecht*.

The usual treatment of alopecia consists in the application of more or less irritating remedies. They are supposed to stimulate the functions of the papillæ and the surrounding tissues, while producing a slight irritation of the skin. In this way they favour the regrowth of the hair. Unfortunately all these chemical agents have a very superficial action, and penetrate with difficulty into the deeper layers of the skin. For this reason *Finsen* and *Jersild* endeavoured to make use of the chemical radiations of light, so that the irritative action should not be confined to the surface of the integument. They had some interesting results, one of which was very conclusive. In this case a series of phototherapeutic exposures set up a slight reaction of the skin, which was followed by a rapid new growth of hair.

We have met with similar results in our own practice. In one case, that of a young female patient, a series of phototherapeutic applications produced a rapid growth of hair on the irradiated surface. Where the compressor of the Finsen apparatus had been in contact with the skin, the fine down of the cheek was replaced by long coarse hairs.

It may be supposed that the X-rays act in a similar manner. We know that the hair papilla is particularly sensitive to this agency. With a sufficient dose we get a withering action on the papilla, and a subsequent alopecia. With a smaller dose we obtain stimulation, which is followed by an increased growth of hair.

According to *Holzknecht's* observations, it would appear that the phenomena of reaction on an area affected with alopecia differ from those which occur in a region normally clothed with hair. Thus an area affected with alopecia is more quickly covered with new hair than a healthy region which has been similarly treated. In the patch of alopecia the papillæ seem to be stimulated to immediate activity by the exposure, as if some obstacle to their growth had been suddenly removed, whereas in the previously healthy skin

the new growth does not commence until the papillæ have recovered from a temporary inhibition of their function. In like manner the redness due to an irradiation is more pronounced on an area affected with alopecia than on a healthy portion of the scalp which has been similarly treated.

This may be due to the fact that the papillæ affected with alopecia are less easily irritated than those in a normal condition. Hence a dose which will wither a normal papilla will only slightly irritate the one which is diseased, will raise it from a state of torpor, and determine a new growth of the hair.

Whatever the explanation, the results appear to be due to a process of stimulation—a stimulation probably of a chemical nature.

As *Holzknecht* has pointed out, the method of application will vary according to the nature of the lesion. If the lesion is progressing rapidly and has attacked a considerable portion of the scalp, it is better to irradiate the whole of the scalp. In this case the new growth will not appear as quickly, but any latent foci will be attacked, and the cure will be more complete. On the other hand, if the diseased spots are limited, it is better to irradiate each patch separately.

The rays should be of moderate penetration, corresponding to No. 4 or No. 5 of Benoist's radiochromometer. The total quantity absorbed by each patch should be such as to produce the first degree of radiodermatitis, consisting merely of a slight hyperæmia. This quantity will be about 3 H. or 4 H. There should be an interval of fifteen days between the séances.

The dose is not invariable, for it is well known that a similar quantity may produce different degrees of reaction in different regions of the body. The scalp appears to be but slightly sensitive, whereas the skin of the face is very irritable, the reaction varying in intensity with the delicacy and fineness of the integument. This fact should be borne in mind when treating cases of alopecia of the beard.

The principal technical point to be attended to is the production of an equable irradiation of the whole affected area. This may be accomplished by remembering the rules we have already laid down.

What are the cases of alopecia in which we may hope for good results from radiotherapeutic treatment? The hair follicle must

have retained its integrity. If the alopecia is the result of a severe attack of favus, or of a lesion which has destroyed the follicle, it is evident that the X-rays can have no effect. As regards alopecia, the result of specific disease or of seborrhœa, we have had no experience. It is probable however, that seborrhœic alopecia may be amenable to treatment by this method.

It is, however, in true alopecia areata that radiotherapy is most useful. Experience shows that different results are obtained on patients suffering from apparently identical lesions. Some are improved, others remain stationary, and it is impossible *a priori* to determine how a given case will react to the rays. Probably the previous duration of the disease is a factor which influences the result, the more recent cases healing with greater facility. Cases of general alopecia affecting all the hairy regions of the body do not readily respond to this treatment. According to *Neumann*, a new growth of hair is more readily produced in young subjects.

It must not be forgotten that a large number of cases of alopecia recover spontaneously. These are the cases most readily ameliorated by radiotherapy, which acts by stimulating the fresh growth of hair. The X-rays have no specific effect on alopecia areata, and are most uncertain in their action.

Radiotherapy should only be prescribed in obstinate cases of alopecia, where it will often produce a notable amelioration after other means of treatment have failed.

3. Diseases on which the Action of the X-Rays is as yet Undetermined.

Acne Vulgaris and Acne Rosacea.

At the International Congress at Moscow in 1897, *Dr. Gautier* of Paris reported sixteen cases of acne vulgaris and acne rosacea which had been successfully treated by radiotherapy. Daily exposures were given, lasting five or six minutes, the tube being at a distance of 12 inches. The current in the primary of the coil was 6 ampères, at a pressure of 18 to 20 volts. After the sixth irradiation, the lesions began to improve. The skin desquamated, the redness was diminished, and the telangiectases became less apparent.

At the same congress *Dr. Pokitonoff* of Paris showed a case of

acne vulgaris, in a woman of twenty-three years of age, in whom the disease had persisted since the age of thirteen. This case, which was under *Dr. Gautier's* care, was completely cured after twelve irradiations.

Ullmann reports a case of inveterate acne of the back. After some ten or a dozen exposures a pronounced erythema occurred; the acne nodules became swollen, but did not suppurate. Little by little they dried up, with slight exfoliation of the skin. A complete cure was obtained after fifty séances, leaving an intense pigmentation of the skin.

Hahn reports several cases of acne rosacea ameliorated, while some were entirely cured by this method. Some months after the cessation of treatment there had been no return.

Jutassy and many other authors have observed the disappearance of acne vulgaris during a course of radiotherapeutic treatment directed against a different disease. This led him to employ it in acne rosacea, in the treatment of which he obtained good results.

Schiff and *Freund* report satisfactory results in cases of obstinate acne vulgaris, and also in acne accompanied by comedones.

Freund also reports a case of acne rosacea, and two cases of acne vulgaris. The amelioration was very noticeable, but slow in its appearance. He used exposures of short duration. In the situation of the acne papules a number of red spots remained, which ultimately turned brown, and disappeared after some time. The results, however, were not permanent. In one case a relapse had already occurred, and in the other cases a sufficient time had not elapsed to be certain that there would be no recurrence.

In a case of furunculosis of the neck the use of the X-rays was followed by remarkably good results.

Scholtz has found that these lesions are ameliorated by irradiation, but in his opinion there is no great advantage over other therapeutic measures. The acne papules and comedones disappear slowly and incompletely, and new ones may appear even during the course of treatment.

Campbell reports fifteen cases of acne treated by irradiation. Each exposure was of ten minutes' duration, at a distance of 4 to 6 inches.

The following are his results: In nine cases the cure was com-

plete, and in three of these there was no recurrence. In one case slight pigmentation occurred, but this was unaccompanied by erythema or dermatitis.

In four cases there was partial improvement. Some of the lesions disappeared, whilst others were not affected.

In one case the acne eruption disappeared entirely, except just at the margin of the hair, which had been protected by a shield.

In another case a slight temporary dermatitis occurred after thirty-three exposures of ten minutes each, spread over a period of three months. The treatment was stopped in consequence, and the dermatitis soon abated. Some of the acne spots disappeared, while others were unaffected.

Hyde, *Montgomery*, and *Ormsby* have noticed the disappearance of acne vulgaris after irradiation.

In certain cases the beneficial effects of the X-rays appear to be due to the production of atrophy of the sebaceous glands and hair follicles. With severe and widespread acne, successful results can only be obtained by pushing the treatment far enough to cause atrophy of the sebaceous glands.

The treatment by X-rays can only be regarded as perfectly satisfactory if it is found on further investigation that recurrences do not occur.

In treating cases of hypertrichosis, *Pusey* found that any concomitant acne rapidly disappeared. In consequence of this observation, he submitted a number of acne cases to X-rays. He reports eleven which had improved under this treatment; usually there was no marked reaction, which in his opinion would be prejudicial. He has seen favourable results in acne occurring in female patients at the age of puberty, and also in cases of indurated acne. In these most obstinate cases the results are sometimes most striking: the lesions cease to progress, the redness and infiltration subside, leaving only a few small white cicatrices. These results were obtained in cases which were not otherwise amenable to treatment. Radiotherapy in these cases gave results superior to any hitherto known procedure.

W. L. Heeve reports a case of acne vulgaris of the scapular region cured by the X-rays. No recurrence had appeared after an interval of six months.

Barney has also reported encouraging results.

Bulkley considers the X-rays as exercising a beneficial effect on

acne, and employs them as adjuncts to other means of treatment in this disease.

Lustgarten is not so enthusiastic, as the few observations he had made were inconclusive.

The following is the method employed by *Williams:* The focus-tube is placed at a distance of 8 inches, and the exposure should not exceed ten minutes. This should be repeated three times a week, and intermitted on the occurrence of any reaction. The exposure should be given with great caution and patience, so as to avoid all danger of burning, and the irradiation should extend slightly beyond the margin of the diseased area.

G. E. Pfahler is a strong partisan of this mode of treatment for acne. His conclusions are as follows:

1. Radiotherapy is preferable to any other mode of healing acne.
2. Recurrence is less frequent by this method, and when it occurs the cases are less severe.
3. Severe reaction should not be set up.
4. If dermatitis is avoided, cutaneous atrophy does not occur.
5. The first evidence of reaction should be a moderate degree of erythema, and this should not occur till some considerable time after the irradiation.
6. Erythema is no requisite for a cure. A slight reaction, however, produces a more rapid result.
7. The eyes, eyebrows, and hair, should be carefully protected from the action of the rays.
8. The focus-tube used should have an equivalent spark-gap of $2\frac{1}{2}$ inches. It should be placed at a distance of 10 to 12 inches from the skin, and the duration of exposure should be from five to ten minutes. The current in the primary of the coil should be from 2 to 5 ampères.
9. The treatment should be continued for about three months, the number of exposures varying from twenty to thirty.

Brocq reported a case of seborrhœic eczema and acne which had been treated at Vienna by a course of seventeen radiotherapeutic séances.

The seborrhœa was but slightly modified, while the acne was exaggerated. An alopecia of the irradiated area had supervened.

The X-rays appear to act on the eruption of acne in two distinct ways—first, by causing atrophy of the sebaceous glands, and secondly by setting up an irritative desquamation.

The principal effect is probably due to the direct action of the rays on the sebaceous glands. In common with all other glandular structures, the secretion of these is arrested by irradiation. This arrest of function may go on to complete atrophy if the exposure is prolonged.

If one adopts *Sabouraud's* view, acne vulgaris is a complication of seborrhœa, of which the essential feature is the excess of the fatty discharge from the sebaceous glands. This is caused by a bacillus germinating in the horny lamella which normally closes the pilo-sebaceous orifice.

In this way a veritable cocoon is formed, which blocks the duct and produces a hypertrophy of the sebaceous gland. According to this view a cure, or at all events an amelioration, will naturally result from the use of a therapeutic agent such as the X-rays, which will cause atrophy of the hypertrophied glands.

This is the explanation put forward by *Török* and *Schein*, who in addition attribute a microbicidal action to the X-rays, which in our opinion they do not possess.

Freund considers that the desquamation set up by the X-rays is the immediate cause of cure. This hypothesis seems plausible, for the topical applications most efficacious in treatment of acne have a similar effect. They cure by producing irritation and exfoliation of the superficial layers of the skin.

According to *Gassmann*, the cure of acne rosacea by X-rays is due to a different cause—viz., a destruction or degeneration of the bloodvessels themselves.

At the Broca Hospital we have not as yet treated many cases of acne by radiotherapy. If the ordinary topical applications are not sufficient, we call to our aid a few high-frequency applications, which in our hands have been very successful. As pointed out by *Leredde*, phototherapy is also useful in obstinate cases of acne, and our own experiments in this direction have been most encouraging.

It would seem that radiotherapy should be reserved for obstinate and disfiguring cases of this disease, where other means of treatment have failed. It is a useful maxim always to proportion the activity of the therapeutic agent to the malignity of the disease.

The following is our method of procedure. In a case of generalized acne attacking a great part of the face, the different regions—cheek, chin, nose and forehead—should be treated separately, the hair, lips, eyes and eyebrows being carefully protected by a lead

shield. In order to get an equable irradiation, the focus-tube should be placed at a distance of 5 to 6 inches from the skin. The rays should be of slight penetration—No. 5 on Benoist's scale. If the case is a slight one, or occurring in a young woman or girl, we may begin with an exposure of 2 H. or 3 H. on each area, at the first sitting. If the patient is a man, and the disease is an old and inveterate acne, we may begin with 3½ to 4 H. Even 5 H. may be given if the disease is situated on other parts than the face. After a period of from fifteen to twenty days, according to circumstances, a second dose of similar magnitude may be given, or, better still, a dose rather smaller in amount. Complete cure, or at all events a noticeable improvement, usually occurs after three or four séances.

No reaction other than a slight erythema should be set up; the occurrence of severe dermatitis should be carefully avoided. Even with the greatest caution permanent alopecia of the beard may result, and even after the lapse of a year a certain amount of atrophy of the skin may occur when the treatment has been unduly prolonged.

Keratosis Pilaris.

We have recently treated by radiotherapy a patient suffering from keratosis pilaris of the eyebrows, accompanied by intolerable itching.

We began with small doses, 3 H. to 4 H., with rays of low penetration, once a fortnight. The itching ceased entirely with the commencement of epilation. After a time, however, the pruritus recommenced, and we were obliged to resume the irradiations. In this way we gave fifteen exposures on the two eyebrows, with a dose of 3 H. to 6 H. on each occasion.

No marked reaction occurred. The redness has diminished; the alopecia is complete, and the patient appears cured. There is no itching. The conical elevations around the hairs have disappeared, and there is no perceptible atrophy of the skin.

This result is the more interesting as the patient had an old scar of lupus erythematosus on the cheek, and it was a question whether the keratosis of the eyebrows was not possibly connected with a recurrence of this disease.

CHAPTER III

DISEASES ASSOCIATED WITH SEBORRHŒA

Diseases having a Keratolytic Action.

Psoriasis.

Typical psoriasis does not usually need radiotherapy for its cure. A temporary cure at all events is generally obtainable by external applications aided by internal medication. Certain obstinate varieties, however, remain for years with slight alterations of aggravation or amelioration, in which every varietv of treatment has been tried without result. In these cases, when all other means have failed, radiotherapy often yields satisfactory results.

Albers-Schönberg seems to have been the first to apply the X-rays successfully to a case of psoriasis. After from four to six séances the squamæ could be detached without the appearance of the fine hæmorrhagic points usually found under each scale.

Great caution is necessary on account of the extreme sensitiveness of the skin in these affections.

Dr. James Startin reports a case of psoriasis treated by him in March, 1900. It was in a female of twenty-one years of age, who had a patch of psoriasis of the leg which had resisted all treatment. He gave three exposures at intervals of three days. Fifteen days after the last séance the skin had regained its normal appearance.

According to *Hahn*, psoriasis is favourably influenced by X-rays. The scales are rapidly shed and healing follows. He does not touch on the question of recurrence.

Sjögren and *Sederholm* of Stockholm do not attach any great value to this mode of treatment.

Williams has had satisfactory results in his practice. He repeats the exposure daily, or, better still, three times a week. From six to ten exposures are required for each patch. If the affected

region is of considerable extent, the tube must be placed at a distance of 12 to 15 inches. A powerful coil is required to produce an efficient radiation under these conditions. If sufficient power is not at our disposal, the surface should be broken up into a number of small areas, which should be irradiated successively.

In the treatment of large surfaces, *Freund* places the tube at some considerable distance, and gives exposures of from ten to twelve minutes' duration. If the diseased patch is of smaller extent, he brings the tube nearer and reduces the time of exposure. Patients show a marked preference for this method of treatment. He says, however, that in the five years during which he has employed the X-rays, he has never met with a case of permanent cure of psoriasis. On the other hand, he has frequently seen chronic patches on the elbows and knees, which have persisted for years, completely cleared away by X-ray treatment. Unfortunately a new eruption has generally succeeded either in the neighbourhood of the old patches or on other parts of the body.

Scholtz has also studied the action of the rays on psoriasis. The following is his mode of operation: When the eruption is disseminated over a large surface, as often occurs on the back, he places the tube at a distance of 16 inches from the skin, and gives exposures of fifteen to twenty minutes' duration. During the exposure he moves the focus-tube continually, in a plane parallel to the surface, in order to obtain an equable irradiation of the whole area.

For more localized patches, as on the elbows and knees, séances of ten minutes with the tube at a distance of 12 inches usually suffice.

The irradiations are repeated daily for the first two or three days, then every two days, and subsequently every three days.

Scholtz does not employ any shield of lead or plaster, as he considers it advisable to irradiate not only the diseased patches, but also the healthy skin in the neighbourhood.

Scholtz's experiments have been carried out in various ways. In certain cases, where the patches were symmetrical, one side only was treated by the X-rays so as to have a means of comparison.

Generally speaking, he found that the X-rays had a marked influence on the disease. Most cases were greatly improved, and some were completely cured. Sometimes, after the primary crusts were shed, the surface of the skin was covered with fine furfuraceous scales. Under these circumstances, plasters of chrysa-

robin were used with good effect. He considers that the usual topical applications should be continued for some time after the cure is completed.

He concludes: 'Psoriasis may be conveniently and rapidly cured by radiotherapeutic treatment.'

As regards recurrence, *Scholtz* hesitates to express an opinion. In certain cases he has seen fresh eruptions of psoriasis occur even during the course of treatment, and since the publication of his work other cases of relapse have occurred. This fact reduces the value of the treatment considerably.

Scholtz has made a histological examination of portions of skin affected with psoriasis, which had been treated by X-rays before excision.

'The first specimen was taken from the edge of a large patch of psoriasis occurring on the chest of a patient, and included a portion of the healthy tissue. It had been irradiated on five separate occasions from May 31 to June 6, 1901. The duration of each exposure was ten minutes, the focus-tube being at a distance of 16 inches from the surface.

'On June 8, at the time of the biopsy, the scales were completely detached, and the affected region had become smooth and soft. There was a certain amount of dark-brown pigmentation, which was shared by the healthy skin in the neighbourhood of the patch.

'On microscopic examination none of the typical modifications usually seen in psoriasis were visible. The only change to be made out was that in those portions of the skin which had been irradiated the prickle layer and the corneal layer were slightly thickened. In the dermis there was some infiltration of the papillary body around the subpapillary vessels. The epithelial cells were also modified, as already described.

'Both the diseased and the healthy portions were pigmented in a special manner. In one specimen cells of a peculiar shape were found in the dermis, notably in the papilla and in the vicinity of the palisade layer. Some of these were elongated and others star-shaped, with a nucleus of irregular outline, the protoplasm of which was crowded with large round pigment granules of a yellowish-brown colour.

'Among the epithelial cells of the Malpighian layer also some of these isolated cells were found. In the rete Malpighii, especi-

ally in the deeper layers, the cells contained a fine granular pigment distributed through their protoplasm. In addition to the pigment within the cells, a network of fine pigment granules, closely pressed together, appeared to surround the epithelial walls themselves.

'On closer examination it was found that these granules were not situated between the cells, but that the pigment was deposited in the epithelial cells and in the protoplasmic fibrillæ which pass from cell to cell. This hypothesis is supported by the fact that the protoplasmic prolongations implanted in the basal region of the rete Malpighii are similar in appearance to those which pass between the cells. Moreover, where the pigment was abundant, the protoplasmic filaments did not stain readily, a fact already pointed out by *Kromayer*.

'Further observations,' says *Scholtz*, 'are needed on this subject, as the specimens I possess do not enable me to determine with accuracy the exact position occupied by the pigment, nor the exact means of its production.'

Ullmann has reported some cases of psoriasis treated by radiotherapy. One of his patients had a patch of long standing on the sacrum, which had resisted all the usual applications. He was treated by three exposures, each of thirty minutes' duration, with the result that the patch entirely disappeared after the occurrence of a slight reaction, leaving in its place an area of brown pigmentation. In *Ullmann's* opinion psoriasis is the dermatosis of all others which is most readily affected by the X-rays. It is, however, questionable whether they are capable of preventing recurrence of the disease, and whether this is not sometimes more frequent after treatment by irradiation. On the other hand, in one case a severe psoriasis of sixteen years' duration was totally cured by a course of treatment extending over eighteen months, and hitherto there has been no recurrence.

Ehrmann considers the treatment satisfactory. Like all the usual remedies for this disease, it sets up a slight inflammatory action, and this is the curative agency. As regards recurrence, it is probably as frequent after irradiation as after other methods of treatment.

'Radiotherapy,' says *Kienböck*, 'gives good results in the treatment of psoriasis. In acute cases, with multiple foci, a slight exposure is sufficient, with the focus-tube at a distance of 12 inches,

and a duration of three minutes. In this way the whole surface of the body may be treated.

'A chronic patch needs for its cure a normal exposure of 3 H. to 4 H. The disappearance commences after an interval of six to eight days. Around the situation of the lesion a pseudo-pigmentation occurs, which disappears after some time. No other treatment, external or internal, is required, but irradiation will not prevent recurrence.'

In the treatment of psoriasis of the face, which is of rare occurrence, *Holzknecht* recommends a dose of 2 H., whereas $3\frac{1}{2}$ H. to 4 H. may be absorbed by a lesion on the body. All inflammatory reaction must be avoided. Recurrence is frequent after treatment with X-rays.

Hyde, *Montgomery*, and *Ormsby* have treated thirty-two cases of psoriasis with the X-rays. In every case the results were satisfactory, at least temporarily. From four to ten short exposures at a distance of 10 to 12 inches were usually sufficient, the lesion disappearing and leaving only some pigmentation behind. In benignant cases the patches of psoriasis began to disappear after two or three applications. In common with other experimenters, they observed that after a course of irradiation the usual bleeding points did not appear when the scales were torn off. The appearance of the diseased patches was altered. They lost their scaly and pearly appearance, and became more furfuraceous. In half the cases the disease returned in the course of a few weeks, the fresh eruption appearing indifferently on the irradiated regions or on other parts of the body. In one instance, however, no recurrence had been observed after an interval of eight months.

Dr. Mewborn has cured an obstinate case of psoriasis of the scrotum by the X-rays, but he does not mention if the cure was a permanent one.

Allen has treated a case with success. *Morrow* and *Servell* contest the efficacy of the rays, whereas *Bulkley* considers them to be a useful adjunct to the ordinary modes of treatment.

Bowen of Boston had five successes and two failures in a series of seven cases treated in the year 1903.

Grunmach, *V. Ziemssen*, *Rubinstein*, *Payne*, *Grouven*, *Sharpe*, *Pusey*, *Gamlen*, and others, have employed radiotherapy in the treatment of psoriasis with more or less success.

We have been successful in treating several cases of this disease.

The following is our method of procedure: We employ soft rays, corresponding to No. 5 of Benoist's chromoradiometer. When the lesions are well isolated we protect the healthy skin by a leaden shield. If the patches are disseminated or confluent, we irradiate the whole of the affected surface without attempting to shield the healthy integument.

We place the tube at some distance from the skin in order to insure an equable irradiation, and we give a quantity sufficient to set up a very slight degree of irritation. A violent reaction is not necessary; the quantity should be just sufficient to stimulate but not to destroy the skin.

The action of the X-rays is similar to that of the topical applications in general use, which set up an irritation of the cellular elements so as to modify the condition of their growth. The advantage of the X-rays consists in their power of penetration. They act equally on the superficial and on the deeper layers of the skin, whereas the action of an ointment is entirely superficial.

In general we have obtained most satisfactory results from doses of 4 H. to 6 H. given at a single sitting, or in two exposures with an interval of twenty-four hours. A dose of 3 H. is often sufficient in slight cases, while in one or two instances a second slight irradiation has been required after the lapse of a fortnight.

We may say for psoriasis what *Sabouraud* says for tinea—it is not necessary to give numerous successive séances. A single exposure, or two if preferred, is enough, using rays corresponding to Nos. 4 and 5 on Benoist's scale, and a quantity equal to 5 H. in Holzknecht's units.

With our installation the duration of exposure is fifteen minutes, at a distance of 5 inches from the anticathode. The quantity of X-rays absorbed during this period is about 4 H. On the following day a second exposure of five or ten minutes completes the dose. In cases where the eruption is slight, without much infiltration, a single exposure of fifteen minutes is sufficient. A month after irradiation of a patch of psoriasis only a slight pigmentation remains. In very obstinate cases a second slight exposure suffices to complete the cure.

The process of reaction takes place in the following manner: In those rare cases which are accompanied by pruritus all symptoms of itching rapidly disappear.

Then, the deep red coloration of the psoriasis begins to fade,

especially at the borders of the patch. The healthy skin around the patch becomes of a slight rose tint, and then rapidly turns brown.

The scales become less adherent, and are easily detached by the finger-nail, without leaving the usual hæmorrhagic points. The brown coloration of the edges of the patch becomes more marked, and in about fifteen to twenty days after the exposure the scales are spontaneously shed, leaving the skin soft, faintly reddened, sometimes slightly hypertrophied, with a few furfuraceous scales on the surface. After a time the hyperæmia disappears, leaving behind it a certain amount of pigmentation.

In some cases the patch of psoriasis does not become pigmented after irradiation, but remains of a reddish colour, with slight furfuraceous scales, whereas the healthy skin surrounding the patch becomes of a dark brown colour. This pigmentation is deepest at the extreme border of the area which has been exposed to the X-rays, and gradually dies away on the healthy integument, giving a zebra-like striping to the patient's skin.

At this stage we usually apply a weak ichthyol pomade, or an ointment containing tar or yellow oxide of mercury. *Scholtz* prefers a weak chrysarobin plaster. In a short time the skin regains its normal appearance, the pigmentation disappearing rapidly.

The cases which have come under our treatment were most obstinate ones, in which all other means had failed. All of these were speedily cured—at all events, as far as regards their objective symptoms.

In one case of psoriasis vulgaris, affecting both forearms, we treated one arm by radiotherapy and the other by ordinary external applications. The irradiated arm was speedily cured, while the disease in the other arm was unaltered.

If the psoriasis is recent, a dose of 2 H. or 3 H. is often sufficient, but in these slight cases the ordinary treatment should be tried first; if this fails recourse may be had to radiotherapy.

When the lesions are very irritable the dose should not exceed 2 H., and if they are inflamed and eczematous they should be treated by means of soothing applications before commencing radiotherapeutic treatment.

We do not recommend this method as the ordinary treatment for psoriasis. As we have already said, it should be reserved for the more serious cases, in which it gives most excellent results.

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As regards relapses, we have not hitherto met with any recurrence in those cases which we have treated. Probably there may be a recurrence after radiotherapy, as there is after all other methods of treatment.

Case I.—M. C. C., aged twenty. Chronic psoriasis of four years' duration. No external treatment has had much effect. Treated by *Dr. Brocq*. Has passed a season at La Bourbole without effect. The lesions are limited to the forearms.

November 18,1 903.—The X-rays were applied to an area on the back of the right forearm, which is covered by a group of nummular patches varying from the size of a sixpence to that of a shilling.

The focus-tube was placed at a distance of 8 inches, and the X-rays used had a penetration corresponding to Nos. 4 or 5 on the radiochromometer. The equivalent spark had a length of 1 inch. A 10-inch coil made by Gaiffe was used, with a current of 5 ampères and a pressure of 16 volts, with a break frequency of 1,200 per minute. The exposure lasted twenty minutes, with an absorption of X-rays equal to 2 H. or 3 H. in Holzknecht units. The next day a second irradiation of ten minutes was given to the same area under the same conditions, during which a dose of 1 H. was absorbed.

November 24.—The area which has been irradiated is altered. The scales have been partially shed; the coloration is not the same; the particles, which were of a yellowish colour before the treatment, have become reddish; the infiltration is diminished; the patches are flattened and are no longer raised above the skin; they are only recognisable by their difference of colour, and show a marked contrast to the patches which have not been irradiated.

The left forearm is treated by irradiation, giving a dose of 4 H. On the following day a second exposure of eight minutes is given with a dose of 2 H.

December 20.—The areas treated on November 18 are free from scales, but are strongly pigmented of a brownish-red colour, which diminishes on pressure. The neighbouring skin shows no signs of reaction.

A few small scales may be removed by the finger-nail, but underneath the usual hæmorrhagic points are absent.

A short exposure of ten minutes is made on the right side. The patches treated on November 21 are beginning to fade.

December 22.—All the irradiated patches have disappeared, and the skin has regained its normal appearance.

On the right forearm the pigmentation has been absorbed. On the left forearm a slight brownish discoloration still subsists.

Case II.—M. G., aged fifty-six. Has had psoriasis for the last five or six years. The lesions are localized on the arms, the forearms, the elbows, and the knees. Has been treated by tarry applications, oil of cade, etc., without any result. The patient is probably an alcoholic, and suffers from rheumatism. The patches of psoriasis are of great extent, reddish in colour, infiltrated, and covered by a thick mass of hard scales. Each patch is surrounded by a zone of brownish hyperpigmentation. The patient complained of considerable itching in the neighbourhood of the eruption.

December 14, 1903.—The treatment was commenced by irradiating a large patch 12 centimetres long by 7 centimetres broad on the dorsum of the right forearm. The electric constants were the same as in the previous case.

Duration of exposure, fifteen minutes ; equivalent spark, 2·5 centimetres ; quality of rays, Nos. 4 or 5 ; quantity, 3½ H.

December 15.—A second exposure of ten minutes' duration is given under identical conditions. Dose, 2 H.

December 30.—The irradiated region itches much less, and is not so thickly covered with scales. An erythematous reaction has commenced.

A patch on the left arm is irradiated.

Duration, fifteen minutes ; quality of rays, Nos. 4 to 5 ; equivalent spark, 2·5 centimetres ; quantity of rays absorbed, 4 H.

December 31.—A second exposure is given to the patch treated yesterday. Duration, ten minutes ; quantity of rays absorbed, 2 H.

January 11, 1904.—The patch on the right forearm has completely disappeared. There are no scales, and the skin is soft and supple, although there is an increase of pigmentation. On the left arm the eruption is fading, and the itching has entirely disappeared.

A patch on the knee is treated. This is bright red, covered by thick scales, and discharging here and there.

Duration, twenty minutes; distance, 15 centimetres; quality of rays, Nos. 4 to 5 ; quantity of rays absorbed, 4 H.

January 12.—Second irradiation of the patch which was treated yesterday. Duration, five minutes ; distance, 6 inches ; quality of rays, Nos. 4 to 5 ; quantity of rays absorbed, 1½ H.

January 22.—The arms are nearly cured. No fresh exposures were made.

January 29.—There is no trace of psoriasis on the arm and elbow which have been treated, but pigmentation still persists. A slight patch on the right knee is irradiated. Duration, fifteen minutes ; distance, 6 inches ; quality of rays, Nos. 4 to 5 ; quantity of rays, 2½ H.

January 30.—A second exposure on the same patch as yesterday.

Duration, fifteen minutes ; quality of rays, Nos. 4 to 5 : quantity of rays, 2½ H.

February 10.—All the parts which have been treated are completely cured. There is no sign of infiltration, and no hæmorrhagic exudation on scratching. The skin is hyperpigmented, especially round the periphery of the patches, the centre being less deeply coloured. An ichthyol ointment is prescribed.

February 26.—All the lesions have completely disappeared, and the pigmentation has diminished, especially on the arms, which were treated first.

It should be remembered that before the commencement of the treatment the skin surrounding the diseased patches was already hyperpigmented.

The patient is discharged cured. He was given a prescription containing ichthyol and oxide of zinc.

Case III.—M. M., aged forty-five, suffering from psoriasis of two years' duration, during which time the case has been treated with various ointments, and has considerably improved. On a great part of the body the eruptions have disappeared, and their number has diminished. Several patches on the legs

and knees remain, which have resisted treatment by external applications. The patient complains of a slight amount of itching.

December 18, 1903.—The treatment is commenced by the irradiation of two or three patches on the lumbar region, the largest of which is the size of half a crown. The electrical conditions are the same as in the last case.

Duration, fifteen minutes; distance, 4 inches; quality of rays, Nos. 4 to 5; length of equivalent spark, 2·5 centimetres; quantity of rays absorbed, 4 H.

January 8, 1904.—In the centres of the patches the scales have disappeared. The periphery is of a brownish colour, covered with crusts and fine scales resembling those of seborrhœa rather than psoriasis. The skin is erythematous over the whole of the region which has been exposed to the rays, but the redness is much more pronounced on the diseased patches, on which the hairs also seem to have grown stronger. The itching has entirely ceased.

An exposure is given to a patch situated on the left buttock.

Duration, fifteen minutes; distance, 10 centimetres; equivalent spark, 2·5 centimetres; quality of rays, Nos. 4 to 5; quantity of rays, 4 H.

January 16.—The lesions on the lumbar region are healed, with the exception of a slight amount of erythema and pigmentation. A few scales remain on the left buttock. The skin still exhibits traces of slight reaction.

An irradiation is given to a patch on the lower third of the anterior surface of the thigh, the dimensions of which are 6 centimetres by 3 centimetres.

Duration, fifteen minutes; distance, 10 to 12 centimetres; length of equivalent spark, 2·5 centimetres; quantity of rays, 4 H.

January 23.—On the back there is no appearance of eruption, but the skin of the irradiated area is still slightly red.

The patch on the thigh is improved.

An irradiation is given to the buttock, where a few scales still remain.

Duration, fifteen minutes; distance, 10 centimetres; equivalent spark, 2·5 centimetres; quantity, 4 H.

February 6, 1904.—All the irradiated areas are healed, except the patch on the front of the thigh, which is now subjected to another exposure.

Duration, fifteen minutes; equivalent spark, 2·5 centimetres; quantity, 4 H.

February 19.—There is still reaction in the patch on the thigh. On the left knee there is an annular lesion of the size of a shilling, which has not been treated before.

Duration, twenty minutes; distance, 10 centimetres; equivalent spark, 2·5 centimetres; quantity, 6 H.

March 9.—The patch treated on February 19 shows signs of reaction. It is red, and some of the scales have been shed. A few scales still remain on the left thigh, for which a tar ointment is prescribed. A spot on the right popliteal space is treated, using a 10-plate static machine.

Duration, twelve minutes; distance, 10 centimetres; quality of rays, No. 2; quantity absorbed, 4 H. to 5 H.

March 30.—All the patches which have been treated are healed, leaving only a slight amount of pigmentation.

Seborrhœides.

We have lately employed radiotherapeutic treatment with good results in two cases of seborrhœides not of a lichenoid type, employing moderate doses of about 4 H.

One was an ordinary case of a seborrhœic eczema on the leg, with considerable itching. Both the lesion and the itching disappeared after a slight exposure. A recurrence appearing a month afterwards yielded to a second application of the X-rays.

The second case was an unusual form of seborrhœides of the face, in which ointments, plasters and even scarification, had produced no beneficial effect. The affected parts were covered by a transparent greasy coating.

After a few exposures, the itching speedily disappeared. The redness at first increased, but was afterwards much diminished, and the greasy secretion became less abundant. After a few more applications the case was entirely cured—at least, so far as the objective symptoms were concerned.

The same precautions must be taken as to the protection of neighbouring parts, and the avoidance of reaction, as in cases of acne.

At the first séance a dose of 3 H. to 4 H. should be given according to the region involved, followed if necessary by a second sitting after a fortnight's interval.

The treatment is only applicable to obstinate localized lesions, and recurrences are frequent.

Lustgarten has published cases satisfactorily treated by his method, but his observations are not conclusive.

Case I.—M. H., aged twenty-two. A patch of non-papular seborrhœides on the right leg, accompanied by intense itching, of one year's duration.

February 10.—Irradiation with rays of quality Nos. 4 to 5. Dose 4 H. to 5 H.

February 24.—The day after the irradiation the itching entirely disappeared. The slight infiltration of the skin is removed, leaving only a little redness and a few conical red papules around the hairs.

March 16.—The patch which has been treated is pigmented and desquamating. The patient complains of slight itching. Just above the original lesion there has appeared a fresh patch of eruption, which is treated by a second irradiation of 4 H.

April 8.—There is a slight recurrence in the lesions previously treated. An irradiation of 4 H. is given.

April 25.—Great improvement. A dose of 3 H. is given.

May 25.—The case is completely cured.

CASE II.—Mme. G., aged eighty-eight. A typical seborrhœic eczema of the face, with itching. A most obstinate case, which has resisted treatment by external applications and scarification.

January 22.—Irradiation of the right side of the face. Dose 4 H., quality of rays, No. 4.

February 3.—Great improvement on the cheek which has been irradiated. An exposure of 4 H. on the forehead.

February 8.—The cheek irradiated on January 22 compares very favourably with the other side, which has been treated with external applications only. The forehead is slightly red. An exposure of 5 H. is given to the left cheek.

February 24.—Slight reaction of the left cheek. An exposure of 4 H. on the chin.

March 16.—The chin continues slightly red. There is no itching. All the regions which have been treated are nearly healed.

From April 8 *to May* 11.—Short exposures are given with doses of 3 H. to 4 H. on certain parts of the face which have been hitherto protected by lead shields, such as the alæ of the nose and the eyebrows.

June 10.—The general appearance is greatly improved ; most of the regions which have been treated are completely healed.

October.—The patient is completely cured.

CHAPTER IV

PRURIGINOUS DERMATOSES

The affections which we propose to study in the present chapter differ greatly in appearance, but from a radiotherapeutic point of view we have thought it advisable to group them together, since they are all characterized by the common symptom of pruritus.

In many of these diseases the occurrence of pruritus seems to be the principal factor; it may be the only symptom, or be accompanied by a local lesion of the skin. In the same way the X-rays may act simply on the pruritus, as in the so-called pruritus sine materia, or they may influence the lesions of the skin which complicate the affection. In the latter case the Roentgen rays not only arrest the itching, but exercise a favourable influence on the skin affection which accompanies it.

We propose to pass in review successively the following diseases: pruritus sine materia, pruritus with a papular eruption, prurigo, lichen ruber planus, lichen corneus, and eczema.

Pruritus Sine Materia—Vulvar and Anal Pruritus.

One of the most marked and indisputable effects of radiotherapy is the rapid diminution and cessation of pruritus. Numerous patients whom we have treated by the X-rays for pruriginous affections have been rapidly relieved, but in some cases the improvement has been only temporary.

Sjögren and *Sederholm* have reported cases of patients suffering from anal and vulvar pruritus who have been rapidly relieved by X-ray treatment. If there is no serious cutaneous lesion, and if the regimen is carefully attended to, a permanent cure may follow.

Scholtz also has reported a case of vulvar pruritus which was improved by slight irradiation.

More recently *Pennington* has employed the X-rays in the treatment of anal pruritus with excellent results. He has treated thirteen cases by this method, to the exclusion of all other treatment, general or local. In every case he obtained a perfect cure, with no recurrence after many months. The duration of the treatment varies with the age and gravity of the affection. In the case of a female patient who had suffered for three years, a few exposures completed the cure; whereas the treatment had to be continued for a month in the case of a man whose pruritus was only of two years' duration.

Delherm and *Laquerrière* tried radiotherapy in a patient afflicted for many years with ano-vulvar pruritus, which had received no benefit either from the faradic current or static and high-frequency effleuves. The tube, whose equivalent spark was 5 centimetres, was placed at a distance of 20 centimetres from the skin. The first séance was of one minute's duration, and this was gradually augmented to four minutes. A complete cure resulted after six séances. Four months afterwards there had been no recurrence.

They obtained considerable amelioration in a severe case of pruritus ani with horrible itching, which had been unaffected by treatment with high-frequency currents for a period of three years. At first the séances were repeated thrice a week, and afterwards less often. After a dozen exposures there was great amelioration of the condition, the accession of itching being of very short duration and much less intense. The patient was able to get eight hours' continuous rest, whereas previously he had never had two hours' sleep without interruption.

Oudin has recently published a similar case.

In the treatment of pruritus the rays should be of slight penetration, and the dose should be moderate, for all local reaction should be avoided. In our opinion the dose should not exceed 3 H. or 4 H., repeated every eight or ten days.

In ordinary cases of pruritus a careful regimen should be prescribed, and treatment by high-frequency currents, which are usually very efficacious, should be tried. Only in very severe and obstinate cases should we have recourse to radiotherapy.

Pruritus with Papular Eruption—Circumscribed Neurodermatitis.

In three cases *Scholtz* has found great amelioration following radiotherapeutic treatment of this disorder, and we ourselves have also had very encouraging results in cases where other modes of treatment had failed.

Among others a female patient came under our care suffering from localized itching of an intolerable character. The constant scratching had resulted in a very pronounced lichenification of the affected parts. As a result of irradiation the itching was speedily relieved. This result was noticed on the same evening, and on the day following the exposure. The irradiated surface at first became red ; subsequently the skin became more supple, and assumed a violet hue, which finally turned brown. The itching entirely disappeared. After some time the skin regained its ordinary smoothness and flexibility ; the striæ and quadrangular markings were obliterated, and only a certain amount of pigmentation remained.

After a month's interval the itching had not returned. On some of the other patches the result was not so rapid, and a second irradiation was given after a fortnight's interval.

The following is our method of procedure :

The lichenoid patch is irradiated with a dose of 5 H. or 6 H. at a single sitting. The rays have a penetration corresponding to No. 4 to No. 6 of Benoist's radiochromometer, and three or four exposures are usually sufficient to insure a cure. We employ a localizer to protect the surrounding skin.

Our results were most interesting, as the cases we treated were very obstinate ones, which had resisted all medicinal treatment, and even scarification, with crossed linear incisions.

We do not claim for this treatment that it will effect a radical cure, but it is quite capable of alleviating the suffering of the patient, and in certain cases it entirely removes the objective symptoms. The future will show how far we may hope for a permanent cure.

CASE I.—Mme. J. R., aged twenty-six. Circumscribed neurodermatitis on the left side of the neck, the back, and the thighs.

March 25, 1904.—An irradiation of 4 H. was given on the neck. On the following day the itching of the irradiated area had ceased.

May 3.—The patch is entirely cured. There is no infiltration or itching; only slight pigmentation remains.

March 25 *to May* 20.—Six applications were made in different regions, with medium doses of 3 H. or 4 H., according to the position and state of the integument.

Over the whole of the patches which have been treated the infiltration and itching are improving; in some places the cure is complete, in others a second irradiation after a month was found necessary.

The general condition of the patient is much improved.

CASE II.—L. A., aged thirty-nine. Patch of lichenification on the left leg 8 centimetres by 6 centimetres; very much pigmented, and very pruriginous.

May 14.—Dose, 5 H.; penetration, No. 5.

June 1.—The itching has diminished; the infiltration is less marked, but the skin is slightly red; a second irradiation is given with a dose of 3 H.

When the patient was again seen in October the cure was complete.

A similar cure was effected in four other cases of like nature treated at the same time.

Prurigo.

Scholtz has reported a case of prurigo treated by radiotherapy without any beneficial effect, the side which had not been irradiated healing just as quickly as that which had been exposed to the X-rays.

We had under our care a child suffering from Hebra's prurigo. The disease was of two years' duration, and had not been benefited either by external applications or by the severe regimen to which it had been subjected. Encouraged by the well-known anti-pruriginous effects of the X-rays, we submitted the patient to radiotherapeutic treatment. As the child was obstinate and difficult to manage, we were obliged to bandage it to a plank which was specially prepared for the purpose. Each of the affected regions was treated successively by a dose of 4 H. or 5 H. with rays of feeble penetration, Nos. 4 or 5 on Benoist's scale. A single exposure was sufficient, and the healing occurred in the following manner:

From the very commencement of the treatment the itching disappeared. The pre-existing erythema was accentuated, and the exudation was more abundant for the first few days. Gradually the skin began to desquamate, the excoriations disappeared, and the integument regained its normal appearance, with the exception of slight pigmentation.

The result was very rapid. A second irradiation on the face was required to complete the cure. In the popliteal spaces the

state of the skin was very satisfactory, and there had been no return of itching after a month's cessation of the treatment.

It is important to be on one's guard in irradiating the articular folds, which are very sensitive, and to shield the testicles from the action of the rays, on account of their injurious effects on the cellular elements of these organs.

Putting aside the question of recurrence, we think that this case is of great interest, showing that the X-rays may become a most valuable auxiliary in the treatment of prurigo.

Case I.—M. L. S., aged two and a half years. Hebra's prurigo. The disease first appeared on the right cheek at the age of three months. The lesion has gradually extended, and has now attacked a large number of regions.

The child suffers from violent itching, and exhibits marks of scratching. The skin is red, infiltrated, pigmented, and discharging. In places it presents signs of lichenification. The regions principally affected are the face, the head, the neck, and the popliteal spaces. The case has been treated for a year by external applications without result. As it was impossible to keep the child still, it was bandaged to a plank specially constructed for these cases.

From February 26 to April 25, 1904, seven irradiations were given on different areas, with a dose of 4 H. or 5 H. A single exposure was enough for each region.

May 9.—The cure is complete in all the regions affected, with the exception of the face, which was the last part treated.

The following was the order of the phenomena: After each irradiation, the pre-existing erythema was accentuated, desquamation occurred, the crusts separated, the discharge was arrested, all traces of infiltration disappeared, and the skin gradually regained its normal appearance. The itching usually ceased one or two days after irradiation.

Lichen Ruber Planus and Lichen Corneus.

It would appear that *Scholtz* was the first to apply radiotherapy to the treatment of lichen. His cure is the only one mentioned in the works of *Freund* and *Williams*.

In *Scholtz's* case the irradiations were of short duration, and the lesions disappeared quickly. 'After a few séances,' he says, 'the lesions on the left leg healed with the occurrence of slight desquamation, with or without pigmentation; whereas on the right side, which was not irradiated, there was no improvement with the exception of a slight alteration of the papules.' *Scholtz* allows that the case was not an obstinate one, as the areas which had not been irradiated yielded after a time to treatment with arsenic.

W. L. Heeve has cured a case of lichen planus of the arm after fourteen weeks' treatment. *Zeisler*, *Macleod*, *Pusey*, and more recently *Ullmann*, have also obtained good results.

We have had an opportunity of treating a young woman suffering from lichen planus at the Broca Hospital, who was sent to *Dr. Broch* by *Dr. E. Besnier*. The lesions were not of any great extent, but were accompanied by intense itching. One side was treated by radiotherapy and the other by topical applications. No internal medicine was prescribed.

On the irradiated side the itching rapidly ceased; the lichen papules diminished, and finally disappeared. For the most part one application was sufficient, but for some regions a second exposure was required after a few days' interval.

On the side treated by external applications the amelioration was very much slower; the itching lasted longer, and the papules did not disappear so quickly. During the course of the treatment an eruption appeared on the tongue and mucous membrane of the cheek. This, however, had shown signs of its appearance before the commencement of the treatment.

The exposures were made in the usual manner. The penetration of the rays chosen was No. 5 of Benoist's radiochromometric scale, and the quantity rarely exceeded 4 H. or 5 H. of Holzknecht's units. It is not necessary to use a lead shield to guard the healthy skin, and in many instances this would be impossible. The distance of the focus-tube should correspond to the area of the surface to be treated, and the field of irradiation may be limited by the use of a localizer, which will diminish the issuing cone of rays.

If the itching is violent, as in our case, it usually diminishes on the day following the irradiation, and disappears in two or three days. Frequently an erythema appears on the seventh or eighth day, proportional to the sensibility of the region and the quantity of X-rays absorbed by the skin. After treatment the papules shrink and appear less brilliant in colour, with a fine desquamation on their surface. They usually disappear entirely in fifteen to twenty days, leaving only a slight pigmentation to mark the spot originally occupied by the lesion.

Sometimes the disease, though mitigated, still persists, and the itching returns. A second application of 2 H. or 3 H. usually completes the cure.

Great caution should be exercised in treating these cases. Certain regions of the body are more easily irritated than others. Thus in one of our cases a dose of 5 H. was given to a surface on the inside of the thigh near the knee. A slight dermatitis occurred, with redness and oozing of the skin; whereas we had hardly ever seen a similar dose produce excessive reaction when employed on other regions of the body. These inflammatory reactions, however, are of little importance.

Relapses occur after this treatment, as after every other. Thus we have seen that there was a recurrence in the case reported above.

A second case of lichen planus affected with violent itching came under our treatment. The pruritus was rapidly ameliorated, the lichenoid eruption was modified, and at the present time the case is completely cured.

Complete recovery also resulted in a case of lichen corneus, in which a few large itching papules were scattered over the surface of the leg. A plate of lead was adapted so as to leave only the papules uncovered. A dose of 10 H. was given in two exposures, each of 5 H., on successive days.

The itching rapidly subsided, and some pain occurred in the irradiated part. A month afterwards the papules had undergone considerable modification. On the summit of each a thick crust of a grey colour appeared, which was easily detached.

These crusts fell off a few days afterwards. Where the large papules had previously existed the skin was soft and slightly reddened, presenting a number of punctiform orifices, which ultimately disappeared. On other parts, where the irradiation had been less intense, a second exposure, fifteen to twenty days later, was required in order to complete the cure.

These cures show that radiotherapy has a favourable action on lichen ruber planus and lichen corneus. We are, however, far from advising its use in every case.

In certain cases of lichen planus very simple medication, and even the hot or cold douche, will cure. Other cases, on the contrary, are most rebellious to treatment, and in these radiotherapy will be found useful, provided the lesions are sufficiently restricted in area to render its employment practicable.

In lichen corneus no other method, in our opinion, gives such rapid and complete results as radiotherapy.

Case I.—Mme. C., aged thirty-five. The patient presents a number of spots of lichen planus, disseminated over the body. The itching is very severe. A portion of the eruption is treated with ointment, and another part by the X-rays. The penetrative power of the rays corresponds to Nos. 4 or 5 of Benoist's scale.

March 7 *to* 29, 1904.—Five irradiations have been given on different areas, with an average dose of 4 H. on each occasion.

March 23.—The eruption treated on the 7th is modified, the itching has abated, and the appearance is altered. Some papules on the outside of the thigh which itched violently, are healed by an irradiation of 5 H.

April 5.—The eruption which has been irradiated has disappeared. The part which has been healed by external applications is also improving.

April 27.—A slight dermatitis has been set up on the region treated on April 5. The parts irradiated by X-rays are cured, and there has been no recurrence. The radiodermatitis is treated by a thick paste of zinc oxide.

May 21.—The dermatitis has faded away. A few papules previously healed have reappeared.

Case II.—Mme. B. T. Lichen planus. The eruption is confluent, the skin red and infiltrated. Five exposures have been given on each area, with rays of penetration No. 5. The pruritus has ceased ; the parts which have been treated are improving, while in some places the eruption has entirely disappeared. Since the eruption originally covered a large area, the patient is still under treatment.

Case III.—Mme. G., aged forty. Lichen corneus. The eruption has existed for the last six or seven years. On the left leg are a number of large papillomatous spots which are corneous and of variable size. Of these, three are grouped on the lower third of the limb, while four or five are clustered together on the superior third. The eruption is accompanied by violent itching.

Each group is treated separately, care being taken that the rays act only on the papillomata themselves.

March 15 *and* 16.—Two exposures on consecutive days are given to the lower group, with rays of No. 6 quality, and a total dose of 10 H.

March 31.—The pruritus has entirely disappeared. The patient complains of a slight sensation of pain over the irradiated area. A dose of 10 H. is given to the group on the upper part of the leg.

April 20.—The pruritus has entirely ceased. The lower group is altered in appearance. The papules are covered with thick horny stratified crusts, of a greyish colour, which seem ready to fall off. The papules of the upper group are also covered with hard scales, but are not so thick.

There is considerable pigmentation of the neighbouring skin.

An exposure of 4 H. is given to the lower group.

May 5.—The crusts and scales on the lower group of papules are beginning to fall off.

May 14.—In the lower group the crusts have fallen off, leaving in their place a slightly reddened cicatricial tissue, with fine punctiform depressions. The papules of the upper group are disappearing. An exposure of 3 H. is given to this group.

May 30.—All the papules have disappeared. Their situation is marked by the cicatricial aspect of the skin.

A short exposure of 4 H. is given in order to guard against recurrence.

Eczema.

It may surprise my readers to find this affection in the same category with lichen, prurigo, and neurodermatitis, but the similarity of the action of the X-rays on all these diseases warrants their inclusion in the same class.

Hahn and *Albers-Schönberg* were the first to treat eczema by radiotherapy.

They found that after a certain number of irradiations the discharge and itching ceased, while desquamation and desiccation were arrested. After having treated fourteen cases of eczema, they formulated the following conclusions:

'In a weeping eczema the exudation disappears after one to four exposures, and does not return.

'In pruriginous eczema the itching often ceases after a single application.

'On dry eczema the effect of the rays is most marked.'

Generally a notable change is observed after the fourth séance. The dry patches alter in appearance, becoming smooth and slightly reddened, and the crusts and scales are shed and do not form anew.

Sjögren and *Sederholm* have met with good results in weeping eczema, as also in cases of eczema with lichenification. The result was most striking in patients where there was infiltration and thickening of the dermis.

Of twenty cases treated by *Gron*, eleven were cured.

Scholtz also found that eczema is favourably influenced by radiotherapy. He noticed the disappearance of pruritus after a few séances in all the patients which he treated. In three very obstinate cases, with frequent recurrences, he obtained most striking results. The weeping and desquamation were speedily arrested, and the redness itself improved.

In order to assure himself of the veritable action of the X-rays, he made some experiments on a case of symmetrical eczema. One side was irradiated, while the other side was treated with the usual external applications. The cure was much more rapid on the side which had been exposed to the X-rays. He therefore recommends

radiotherapy for the treatment of obstinate eczema, while abstaining from giving an opinion as to the infallibility of the method or the frequency of recurrence.

Williams has also obtained some success in the radiotherapeutic treatment of eczema.

Freund's experience confirms that of *Hahn* and *Albers-Schönberg*.

Grunmach, *V. Ziemssen*, *Jutassy*, *Sharpe*, *Payne*, *Schiff*, *Bowen*, *Pusey*, *W. L. Heeve*, and *Gamlen* also report satisfactory results.

It is probable, as Pusey says, that the X-rays influence eczema by stimulating the bio-activity of the cells.

Moreover, the local irritation produced by the X-rays resembles that which results from other therapeutic treatment. In certain cases, as is well known, a satisfactory result can only be obtained by alternately irritating and soothing the affected skin.

We have ourselves obtained a complete cure of the local lesions in cases of eczema. Most of our patients are still under treatment, but there has been no recurrence in the regions which have been irradiated. Many were cases of weeping eczema, with slight inflammatory reaction. There can be no doubt that irradiations of moderate intensity completely arrest pruritus. The oozing is also speedily diminished, and the infiltration becomes less and finally disappears, after which the skin speedily regains its normal appearance.

Usually we give a dose of 3 H. or 4 H. to each eczematous patch. This dose may be modified according to the condition of the skin and the appearance of the lesion.

When the disease is recent and very irritable, a dose of 3 H. should not be exceeded. If in the course of eight or ten days no amelioration has been produced, a second exposure may be given.

A dose of 4 H. or 5 H. is required for a chronic patch of eczema, with thickening and infiltration of the skin.

A single application is frequently sufficient.

Some authorities consider that all local treatment is useless, and that until the general health is improved constant local eruptions will recur. In this opinion we concur, but there is nothing to hinder our giving careful attention to the general health in addition to local treatment. Radiotherapy will in no wise replace careful regimen and hygiene. It takes the place of topical applications,

and to deny its efficacy is to deny the utility of all ointments, plasters, and external applications whatever.

What makes the X-rays so valuable is the fact that they are efficacious in certain forms of eczema which are rebellious to all other local treatment. It is in the more obstinate, chronic, and recurring types that they are most useful.

We do not consider that the rays should be employed in acute eczema in process of eruption or in irritable cases.

Radiotherapy is a means of treatment only to be used in exceptional cases.

Case I.—Mme. H., aged fifty-one. The patient exhibits a number of patches of weeping eczema, with infiltration of the dermis. The itching is severe, and marks of scratching appear on the skin.

February 11 *to May* 17, 1904.—The patient has had eight exposures on different patches, with rays of No. 5 penetration, and an average dose of 4 H. to 6 H., according to the state of the skin and the extent of infiltration. The itching has ceased, the crusts have fallen off, the infiltration has disappeared, and most of the patches are entirely healed.

Three other cases have been greatly improved, but are still under treatment.

October.—All the above cases are cured as far as regards the local lesions.

CHAPTER V

THE ANALGESIC ACTION OF THE X-RAYS

There is no doubt that when the X-rays are absorbed by a painful region they possess the power of alleviating the pain.

In treating cancerous cases by X-rays in order to act on the neoplasm, we often find the pain is rapidly diminished, and sometimes entirely disappears after the first few exposures. All authorities who have studied the question are in accord on this point.

At the Congress of Angers in 1903, the report of *Guilleminot*, *Weil*, and *Bloch* was conclusive. In our own practice we have always seen a diminution of the pain even in those severe, widespread, and inoperable cases where alleviation was the only result to be hoped for. This of itself is a most important fact, and affords a clear indication for the use of radiotherapy in these cases.

The pain usually ceases on the evening of exposure if this has been intense, or on the next day. The duration of freedom from pain varies considerably in different subjects, but on its recurrence a second slight irradiation will generally suffice to allay it. We are not in a position to say how long the treatment will prove efficacious, or if the action of the rays will in time wear itself out. This is improbable, however, as the tissues get more and more sensitive to the action of X-rays the longer the duration of the treatment.

We may quote the case of a man who was sent to the Broca Hospital by *Dr. Lermoyez*, suffering from an epithelioma of the ear, with invasion of the mastoid process and deep tissues in the neighbourhood. The case was inoperable, and the patient suffered horrible agony in the ear, which totally prevented sleep. By *Dr. Brocq's* advice he was treated by the X-rays, in the hope of acting on the neoplasm itself, and more particularly on an ulceration of the

external ear. The dose administered was about 5 H. or 6 H. On the next day the patient assured us that he had passed a better night. We gave a second exposure, in order to complete the prescribed dose of 10 H. For a period of two or three days the pain was slight and quite supportable, and the patient was able to sleep during the night. After each irradiation the same phenomena occurred. It would be better in a similar case to give fractional doses, so as to permit of more frequent irradiation, since a small dose of 3 H. or 4 H. is sufficient to produce alleviation of pain.

Some statistical observations made by *Skinner* seem to show that the analgesic action is less certain in the case of deep-seated tumours than it is on superficial cancers. In our own experience, it has seemed to be equally beneficial in both cases. The following are *Skinner's* results:

Permanent relief of pain in		14	cases
Temporary	" "	2	"
Partial	" "	8	"
No improvement	"	14	"
Cases where pain was absent		5	"

The analgesic properties of the X-rays has been used with success in other painful diseases.

In 1899 *Freund* reports that *Grunmach* had most encouraging results with the X-rays in cases of neuralgia and articular rheumatism.

In thirty-eight cases of neuralgia treated by this method, *Stembo* obtained twenty-one cures. The number of séances varied from three to ten, with a duration of three to ten minutes each.

Freund reports a great diminution of pain in a case of severe trigeminal neuralgia where morphia injections had given no relief, whereas a second similar case proved refractory to the influence of the rays.

Allen and *Bondurant* report good results, as also does *Hildebrand*, who uses hard tubes for the treatment of neuralgia.

In a case of trigeminal neuralgia treated by *Gocht*, the amelioration was rapid, but the pain returned after some time.

W. Sweet of Philadelphia has attempted to prove a special action of the X-rays on the nervous system. According to his observations, the skin after intense irradiation loses a portion of its

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sensibility, so that superficial incisions may be made in it without the patient feeling much pain. We have never met with any such phenomenon in our own experience.

It is quite clear, then, that the X-rays exercise an analgesic effect in cases other than cancer. In a patient under our care suffering from tabes, who had a patch of cutaneous hyperæsthesia on the back, a few slight irradiations produced a notable diminution of the pain.

We have also seen a case of facial and intercostal neuralgia yield rapidly to this treatment; and *Bisserié* has reported similar cases at a recent séance of the Société de Dermatologie.

Certain painful sensations, ordinarily described as rheumatic, also yield to this treatment.

The results obtained by *Darier* and *Zimmern* by the action of radium in tabetic cases are in confirmation of the foregoing observations, since the phenomena are probably of a similar nature.

Some authorities think that the results are due to suggestion, or some such psychic phenomena. This can hardly be the case. In cancer, for instance, the relief may be due to a diminution of pressure on the nervous filaments, or are these influenced in a more direct manner?

Unfortunately the sedative action for pain is not always constant. Certain cases prove rebellious to the treatment, and it is impossible to say *a priori* if it will be successful in a given case.

Nevertheless radiotherapy is an easy method of treatment, and should always be tried in obstinate cases of pain, since even if it is not successful, it has no dangerous consequences to the patient.

The tube should be placed at some distance from the painful region, so that it may be completely irradiated. The penetration of the rays should be about Nos. 7 or 8, but this may be varied in accordance with the position of the painful spot.

The dose should be 3 H. to 5 H., according to the region to be irradiated, and the séances may be repeated every eight or ten days.

It is advisable not to give a less dose than 2 H. or 3 H. at each exposure, since in some cases of carcinoma irradiation with very small doses of ½ H. to 1 H. appears to have been followed by an aggravation of the pain, due perhaps to a stimulating action of the X-rays.

We must trust to the future to throw more light on the subject. At present we can only record the results of observation, without attempting to establish a true pathogenesis.

CHAPTER VI

DERMATOSES PRODUCED BY A SPECIFIC MICRO-ORGANISM

Lupus Vulgaris.

Schiff of Vienna first applied the X-rays to the treatment of lupus vulgaris. His first attempt dates back to 1896, and was reported in the *Archiv für Dermatologie und Syphilis.*

The first case treated by radiotherapy was reported in the same journal in 1897, but the technique was not given in detail till 1898, when, in collaboration with *Freund*, he published it in the *Wiener Klinischer Wochenschrift.*

In 1897 *Kümmel* reported to the Twenty-sixth German Congress of Surgery a case of lupus treated and cured by the X-rays. At the Twelfth International Congress at Moscow, soon afterwards, *Schiff* and *Freund* exhibited two successful cases, and these were speedily followed by the work of *Gocht* and *Albers-Schönberg.*

Since then publications on this subject have multiplied, and it would be difficult to enumerate the many authors who have treated this question.

According to *Schiff*, the following is the method of cure. The Roentgen rays set up a general inflammatory reaction of the whole of the irradiated surface. In addition, there is a specific reaction of the diseased tissue, so that nodules of lupus become apparent which were not previously visible. These are gradually detached and disappear, and any lymphatic glands which may be enlarged are diminished in size. *Schiff*, moreover, obtained excellent results in several severe cases where the mucous membrane was involved, and drew attention to the existence of individual idiosyncrasies which often influenced the rapidity of cure.

At first *Schiff* advocated the production of sharp reaction, but

he has since modified his opinion, and is now content with the production of a simple hyperæmia.

'The constancy of my results,' he says, 'furnishes an incontestable proof of the excellence of my method.

'In the course of years, this method has undergone certain modifications. I no longer consider it necessary to provoke an energetic inflammatory reaction with the view of destroying the diseased tissue. At present I consider that it is sufficient to give such an irradiation as will produce a slight degree of hyperæmia.

'Some years ago, in conjunction with *Freund*, I showed that the cumulative action of the rays was sufficient in most cases to secure a favourable result. The duration of treatment is in this way considerably diminished, since it is no longer necessary to await the termination of reaction before proceeding to give another exposure.

'I now endeavour to avoid all intense reaction, and employ a hard tube with a minimum dose of the rays. The amount absorbed may be regulated by altering the duration of exposure, and by varying the distance of the tube.'

In some of the cases which he has reported there has been no recurrence after a period of over three years. *Schiff* has added some very interesting photographs to his work.

Albers-Schönberg has treated a large number of cases of lupus successfully. He commences with séances of ten minutes, and increases the duration gradually.

At the Congress of 1902 *Neisser* reported that he had not had satisfactory results in his treatment of lupus by radiotherapy. This is accounted for by the severity of the cases treated in the clinique at Breslau, which necessitates energetic measures and a long and difficult treatment.

Gassmann has published four cases of lupus treated by the X-rays —viz., one of the ear, one of the nose and lips, one of the face and hand. Some interesting photographs accompany his paper.

Encouraged by the cases published in Germany, *J. A. Lee* used the X-rays in the treatment of a case of lupus of the side of the nose invading the internal angle of the eye. The amelioration was most marked; cicatrization was speedily produced, and a complete cure ensued.

Gron did not obtain encouraging results.

Gaston, *Vieira*, and *Nicolau* were not satisfied with the X-ray treatment, obtaining a cure only after forty applications. On the

other hand, they report a favourable result in a case of tuberculosis of the skin.

Of three cases treated by *Pusey* in 1901 two were cured, the cicatrices being soft and barely visible. *H. R. Barney* had ten successful cases out of twelve treated by this method. *Bulkley* had good results in a severe case of lupus of the chin, and *Bowen* had several encouraging cases.

Scholtz has treated several cases of lupus, among which were some of a very malignant type. In one instance he obtained a complete cure, which has already lasted over a year. He says: 'We get successful results in cases of lupus which are quite incurable by ordinary therapeutic means. The treatment does not generally last more than a few months, and may be continued at the patient's home.

'The cosmetic results are better than those obtained by scraping. In benign and superficial cases a cure may often be obtained by a long-continued series of slight irradiations, separated by considerable intervals, without the production of any severe dermatitis.'

H. E. Gamlen considers that the result is in great measure dependent on the care with which the treatment is adapted to the varying requirements of each case. He usually exposes his patients to an irradiation of five minutes two or three times a week. At the commencement he endeavours to set up a slight reaction, which is increased gradually as the treatment progresses. On the question of recurrence he is silent.

Allan Jamieson has treated a certain number of lupus cases. He considers phototherapy to be preferable to the X-rays. It is true the results of the former are slower, but the physician is able to avoid the serious accidental burns which sometimes follow radiotherapeutic treatment.

G. E. Pfahler cured a case of lupus of the chin and lip which had invaded the mucous membrane. The lesions of the skin and of the mucous membrane disappeared at the same time, although the irradiation was given to the exterior surface only.

Ullmann has published several cases of lupus which have been greatly ameliorated by radiotherapy, and some of which have been entirely cured from a clinical point of view.

In a case of recurring lupus in the neighbourhood of the ear, he gave an exposure of 5 H. with a soft tube, which resulted in a sharp reaction and superficial ulceration.

At the end of three or four weeks the ulceration had healed. and the lesion was greatly improved. The author hopes there will be no recurrence in this case, and considers the method of treatment a very practical one.

He believes that better results follow in the more exuberant forms of lupus, such as papillomatous forms of sclerous lupus, than in disseminated forms of nodular lupus vulgaris.

Freund has published a case of lupus which was cured without any reaction other than a slight erythema.

'In plane varieties of tubercular lupus with ulceration,' says *Kienböck*, 'radiotherapy gives good results; but *Finsen's* phototherapy seems to give even better results, both as regards a radical cure and from an æsthetic point of view. Hypertrophic forms of lupus should be treated at first by the X-rays, which produce a considerable decrease in the volume of the lesion, and afterwards by phototherapy.

'It is very rare to entirely cure a case of lupus by radiotherapy, but it may be greatly ameliorated. In all cases tardy atrophic changes of the skin supervene, with discoloration and telangiectasis.

'The irradiations are given only at intervals of one or two months, and at each exposure a normal dose of 3 H. to 4 H. is given; by this means the occurrence of too strong an inflammatory reaction is avoided. Eight days after exposure the nodules begin to diminish in size, and the ulcerations to heal; or, if the dose has been stronger—5 H. or 6 H.—a fresh ulcerative process is set up, increases, becomes stationary, and finally ends in atrophy of the skin. We have, therefore, a primitive atrophy, due to degeneration of the cells of the lupus nodules, and a secondary atrophy set up by the inflammatory reaction.'

Holzknecht also distinguishes various forms of lupus, and lays down for each variety the treatment which is preferable.

He does not recommend the X-rays for the plane variety of lupus, with small, isolated nodules, since the results are not constant, and a cutaneous atrophy may be produced. In ulcerated lupus, without hypertrophy, a dose of 3 H. may be given if it is to be followed by a course of Finsen's treatment.

If Finsen light is not used, the dose may be increased to 4 H., and this may be repeated two or three times until definite improvement supervenes.

In hypertrophic forms, with or without ulceration, there are two distinct modes of procedure.

The first method is seldom employed, although it is perhaps the better of the two. It consists in giving small doses of 2 H. at intervals of a fortnight for a period of three or four months, or until some improvement occurs. The treatment is then interrupted until all inflammatory reaction has disappeared. The irradiations may then be recommenced if necessary.

The second method consists in giving a dose of 3 H. to 5 H. once a month for a period of five to ten months.

He adds that a complete cure rarely follows without having recourse to the Finsen treatment in addition to the X-rays.

In 1904 *Béclère* presented to the Société de Dermatologie a patient suffering from lupus of the foot, which we had previously examined with him at St. Antoine, and which was greatly improved by X-ray treatment. As Béclère said, 'Where the domain of ultra-violet light ends, there that of the more penetrating Roentgen rays begins.'

In August, 1904, *Dr. Augé* communicated to the Congress of Grenoble two cases of lupus vulgaris cured by radiotherapy. The photographs, taken before and after the treatment, are very instructive. Unfortunately, the author was not able to furnish any exact measurement of the quantity of rays absorbed. He treated the case with fractional doses in order to avoid reaction. He thus concludes: 'In spite of the success which is claimed for the sister treatment phototherapy, radiotherapy is indicated in the treatment of all cases of widespread lupus.'

At the same congress *Dr. Reboul* of Nîmes reported a case of tuberculous lupus of the upper lip, which was cured after a series of fifteen radiotherapeutic exposures.

Some authorities consider it advisable to combine other modes of treatment with radiotherapy. Thus *Gassmann* uses pyrogallic acid, electrolysis, Holländer's procedure, or cauterization, as adjuvants to the Roentgen rays. *E. Smales*, following *Harper* of Nottingham, recommends the administration of urea, while *Gibson* advises the use of high-frequency currents in conjunction with radiotherapy.

In conclusion, the following authorities may be mentioned as having obtained more or less satisfactory results by this method of treatment: *Himmel*, *Thurnwald*, *Spiegler*, *Pang*, *Ziemssen*, *Schenkel*, *C. Schmid*, *Grunmach*, *Sharpe*, *Hall-Edwards*, *Sholefield*, *Rona*, *Greenleaf*, *Jutassy*, *Neumann*, *Lion*, *Schell*, *Sjögren*, *Sederholm*,

Clark and *Smith*, *Geyser*, *Jones*, *Knox*, *Lapinski*, *Kirmisson*, *Norman Walker*, *Judassohn*, *Van Dort*, *Jeney*, *Du Castel* and *Foveau de Courmelles*, *J. de Nobele*, *Stenbeck*, *P. R. Egau*, *G. H. Radman*, *J. C. Squance*, *P. A. Morrow*, *Malley*, *Fox*, *Jamlen*, *Wild*, *Rockwel*, *Kinnaird*, *Hoffmann*, *Duhot*, and others.

Method of Procedure.—If one glances at the various publications relative to the treatment of lupus by the X-rays, one is struck by the great variety of methods employed by different experimenters. In all cases the object is the same—viz., the destruction of the lupus nodules. This end is attempted by two distinct methods—either by producing a gradual effect, or by setting up a sharp reaction, followed by a superficial necrosis of the integument.

The first is the method of *Schiff*, *Albers-Schönberg*, *Hahn*, *Grouven*, *Kümmel*, and others. They endeavour to avoid the production of acute dermatitis, which is in their opinion not only useless but noxious, and retards the cure. They seek to produce a simple hyperæmia. A slight swelling of the irradiated area, and more especially of the lupus nodules, follows, accompanied in certain cases by some amount of pain. The congestion and swelling speedily passes, the nodules diminish in size, the redness becomes less intense, and in ulcerated cases a white cicatrix without any retraction remains behind.

To attain this end they give exposures of from two to ten minutes' duration twice or thrice a week, and suspend the treatment on the appearance of any objective symptoms. *Williams* of Boston gives exposures of short duration, and thinks that the patient has nothing to gain from the onset of a violent reaction.

The second mode of procedure is to a certain extent a method of cauterization, and consists in destroying the lupus focus at once by setting up intense radiodermatitis and superficial necrosis. *Lion* prefers this method, which has also been carefully studied by *Scholtz*. We quote his words :

'According to my clinical experience, supported by microscopic examinations, I may assert that intense irradiations, followed by excoriation and superficial necrosis, are more efficacious than slight exposures. By either method the process of healing is the same—*i.e.*, inflammatory reaction, breaking up of the lupus nodules, and replacement of the diseased tissue by a new formation—with this difference only, that the phenomena are much more rapid when the

irradiation has been intense, and that the effect in this case is more marked in the deeper layers.

'We do not understand,' he says, 'why operators are so anxious to avoid superficial ulceration of the skin, and we consider that intense irradiations are most efficacious in severe forms of lupus and many other diseases.'

He warns the reader to avoid deep necrosis and gangrene, which may require months to heal, and sometimes even years. The superficial ulcerations consequent on this method usually heal but slowly, although in some cases the reparation is more speedy. The after-treatment dressings may be carried on at the patient's own house.

The cicatrices obtained in this way are fine and delicate, and have a slightly atrophic appearance. The results, although imperfect, are usually better than those which can be obtained by any other means.

It must not be understood that *Scholtz* rejects *in toto* the gentler treatment advocated by *Williams* and *Kümmel.* He has made a comparative study of the two methods, which does honour to his critical sagacity.

'In my opinion,' he says, 'it is impossible to lay down a uniform rule which is applicable to every case.

'One cannot say, *a priori*, which method will give the best results—that which sets up ulceration, or that which produces a moderate reaction. Each has its advantages and its drawbacks. In some cases there is a definite indication for one in preference to the other. In all instances the treatment should be individualized. It is in our opinion wrong to take as an axiom that all reaction should be avoided which would produce inflammation, excoriation or superficial sloughing.

'The question whether we use a powerful irradiation and superficial sloughing, or more moderate exposures continued for a month or more, with interruptions, in order to avoid intense reaction, depends on the gravity or the benignity of the lupus, its position and the time at our disposal.'

In superficial and benignant cases of lupus, severe reaction should be avoided. The dose should be so proportioned as to produce only a faint redness, followed by a slight œdematous swelling. In most of the cases which we are called on to treat there is a good deal of infiltration, with ulceration of the nose, the lips, or the

skin, and the mucous membrane is often involved. Frequently the patients come from a distance, and can only remain for a few weeks in hospital.

In these cases we usually commence at once with irradiations powerful enough to produce necrosis of the affected region. From the above remarks it is evident that different methods are indicated with different circumstances.

In severe cases of hypertrophic lupus we may act with greater energy than is permissible in the case of benignant and superficial lesions.

The destructive method is the more radical cure and the treatment is of shorter duration, since it is suspended as soon as the dose necessary to produce ulceration has been given—unless, indeed, a second intervention is required to treat any lupus nodules which may have escaped destruction.

In *Freund's* opinion, the patient does not derive any great benefit from the rapidity of this process. The ulceration following the destruction of a large patch of lupus may take many months to heal. In a case mentioned by *Albers-Schönberg*, cicatrization was not completed till 130 days after the commencement of treatment. The pain accompanying the ulceration is frequently so violent that radiotherapy loses one of its chief advantages, its painlessness.

At the Broca Hospital we have treated a certain number of patients affected with lupus, but our results hitherto have not been very satisfactory. The installation at our disposal does not admit of our treating any but severe cases, where other means have failed.

As we have already observed, the X-rays exercise a selective action on lupoid tissue, which seems to possess a special sensibility to their action. The diseased tissue reacts more violently than normal tissue, and the reaction is usually accompanied by more or less pain.

We have tried the two methods—that by intense irradiation and that by moderate doses. It is most difficult to tell in advance the degree of reaction which will result from a given dose, especially if we are desirous of obtaining a certain degree of irritation without producing ulceration. The susceptibility varies according to the situation of the lesion, its area, its depth, its appearance, the degree of infiltration and the state of the integument. Usually a dose of 8 H., of penetration Nos. 4 or 5, will produce severe erythema and slight swelling; but in one of our cases the same dose on the

thin atrophic skin of the arm was followed by an ulceration of a month's duration. It is true that the more violent reaction was followed by better results. This patient was subjected to a second irradiation of 4 H. or 5 H., producing further ulceration, which is only now undergoing cicatrization.

A case of lupus tumidus non exedens, affecting the eyebrow, has been under our treatment for the last four or five months. It has greatly improved under a course of moderate exposures repeated every three weeks, with medium doses of 4 H. to 7 H. on each occasion. No ulcerative dermatitis has occurred, and at the present time there only remains a small portion unhealed. This is an interesting case, as this form of lupus is but little affected by scarification, and the position of the lesion renders treatment by phototherapy very difficult.

Another case of severe lupus of the cheek was exposed to an intense irradiation of 9 H., the reaction appearing after five or six days. The whole surface was reddened, turning grey after a time, and a superficial ulceration supervened. Cicatrization has commenced and the wound appears healthy, but it cannot be said that the patient is completely cured. The case is still under treatment.

Taking into consideration the indications given above, we may now proceed in our attempt to fix the dose required for the treatment of lupus vulgaris.

The X-rays should be of slight penetration, corresponding to Nos. 4 and 5 on Benoist's radiochromometric scale. At each séance a dose of 3 H. or 4 H. may be given, without producing more than a slight swelling and erythema. In order to set up superficial ulceration, a dose of 7 H. or 8 H. must be absorbed by the diseased lupus tissues.

Some forms of lupus would seem to react more quickly than others. In lupus tumidus non exedens, and like forms, the dose should be greater than in ulcerative lupus. In the former case a dose of 5 H. or 6 H. may be given in a single exposure without danger of dermatitis. A dose of at least this amount is required for the treatment of lesions which are deeply infiltrated.

In hypertrophic cases, whether ulcerated or not, 4 H. or 5 H. may be absorbed every fifteen or twenty days as long as violent reaction does not supervene.

In smooth and ulcerated forms the rays often produce rapid

amelioration, but in cases where the skin is ill nourished it is prudent not to exceed 3 H. or 4 H. if ulceration is to be avoided.

The interval between the successive exposures may be twenty to twenty-five days, according to the severity of the inflammatory reaction. Although excellent results often follow energetic treatment, yet in most cases it is better to be satisfied with a moderate reaction. Severe treatment should be reserved for those more obstinate cases in which moderate irradiations have been tried with only partial or temporary success.

This opinion is shared by *Lancashire*, who considers that ulceration should, as a rule, be avoided, although it is frequently followed by a complete cure. In his opinion the irradiations should not follow one another too closely, since amelioration continues long after the cessation of treatment. It is not necessary to push the exposure so as to cause ulceration. With a reaction far short of this, the lupus nodules at first become more apparent, and swell up, afterwards shrinking and softening until they are gradually absorbed.

Gassmann is also of opinion that ulceration should be avoided, as it is a dangerous and painful procedure. A slough, even when superficial, is always painful and requires a long time to heal. If the ulceration goes deeper, as is very possible, grave complications may arise, one of which is permanent disfigurement from scarring. The reaction therefore should in all cases be limited to the production of a moderate degree of erythema.

The next question to be considered is the duration of a course of radiotherapeutic treatment.

As a result of our own experience, and the study of the reported cases, we have come to the conclusion that radiotherapy alone is but rarely capable of determining the cure of a lupus patch.

At the commencement of treatment the results are marked, and one is often astonished by the rapidity with which amelioration occurs.

After a time, however, the condition of the lesion becomes stationary. Under these circumstances the lesions should be attacked by other means—thermocautery or phototherapy—as recommended by *Kienböck* and *Holzknecht*.

Indications for Treatment.—What are the indications for radiotherapy—*i.e.*, in what cases should it be preferred to other methods of treatment?

In *Lancashire's* opinion the X-rays are indicated in all cases of lupus vulgaris which are too extensive to be treated by Finsen's method. They should be used also in ulcerated cases with much cicatrical tissue, and when the mucous membrane is affected.

Many authors agree with *Neumann* in considering that the X-rays should be reserved for ulcerative lupus of the face, isolated lupus nodules scattered through the skin, lupus of the aponeuroses and the muscles, and for lupus of internal cavities.

Thurstan Holland, who has made a special study of the indications for the use of the X-rays, agrees with *Williams* that this method should be tried first, since the results are not so satisfactory when other therapeutic treatment has preceded that of the rays. He recommends radiotherapy, not only in chronic and obstinate cases, but at the very commencement of the disease.

C. A. Greenleaf agrees with this view, and maintains that patients who have not been subjected to surgical interference are more amenable to the action of X-rays. In his opinion, the rapidity of cure is in inverse ratio to the severity of the previous surgical intervention.

Schiff, on the contrary, considers that extirpation, followed by grafting, is the ideal method of treatment for those circumscribed lesions which are easily accessible. Radiotherapy, on the other hand, should be employed in cases of lupus exedens, in ulcerated forms, or when the mucous membranes or other inoperable tissues are invaded.

Morris and *L. Doore* prefer the Finsen treatment, since in their opinion the X-rays rarely produce a complete cure. They are indicated in such cases as lupus of the mucous membranes, when a sharp reaction should be set up in the affected region.

In 1903 *Scholtz*, in a treatise on the treatment of skin disease by the X-rays and by concentrated light, thus sums up the indication for radiotherapy :

'In lupus of the face without ulceration either phototherapy or the X-rays may be employed. In cases of ulcerated lupus radiotherapeutic treatment should be preceded by the use of pyrogallic acid ointment of gradually increasing strength. In severe and deeply infiltrated cases the treatment should be begun by curetting and the hot-air cautery, followed by the use of pyrogallic ointment in combination with the X-rays, and the cure should be completed by the application of phototherapy.'

Wild of Manchester gives the statistics of results obtained by radiotherapy and by the Finsen treatment. Of twenty cases treated by phototherapy, eleven were completely healed and four were improved, thus giving satisfactory results in 75 per cent. of the cases treated. With the X-rays, of twenty-nine treated nine were cured and nine others were improved, thus giving good results in 62 per cent.

The condition of the patient, as well as that of the lesion, must be taken into account in considering the indications for X-ray treatment. As regards the patient, we must take into consideration his susceptibility, his position in life, the time at his disposal, his age, his courage, and other factors. As regards the lesion, we have to consider its severity, its extent, its situation, and the variety of the disease. We see then that the indications for radiotherapeutic treatment are not identical with those for phototherapy ; the former can by no means entirely replace the older methods employed in the treatment of lupus.

The effect of the X-rays seems to be analogous to that of the chemical rays of the spectrum ; they may therefore be supposed to act more or less in the same way as phototherapeutic radiations, both methods acting primarily by stimulating the production of cicatricial tissue. From a theoretical point of view the Finsen treatment would seem to be inferior to the Roentgen rays. The former necessitates the compression of the skin, which is most difficult to realize, whereas the latter acts at a distance, without any necessity for compression and its accompanying pain, thus enabling cases of ulcerative lupus to be treated with great facility.

With radiotherapy a large surface may be attacked at one sitting, whereas the field of action in Finsen's treatment is much restricted. Even with the most recent apparatus, as perfected by Finsen, Lortet-Genoud, Broca-Chatin, Marie, and others, a long series of tedious séances is required, and the treatment may extend over months or even years. It is true that with the X-rays the treatment may be prolonged, but when massive doses are used, the patients are not compelled to visit the hospital several times a week for months, as in the Finsen treatment.

Lastly, the Roentgen rays have a power of penetration vastly superior to that of the ultra-violet radiations, enabling them to act on the deeper layers, whereas the action of light is restricted to the more superficial tissues. Phototherapy cannot be of much use

in inveterate cases of lupus, which have been frequently treated, and where there is a quantity of cicatricial tissue in addition to the lupus lesions, since the chemical rays will be arrested by the cicatricial tissue. The X-rays, on the contrary, will readily traverse this, and thus be able to attack the deeper foci of the disease.

To counterbalance these theoretical advantages, radiotherapy has some drawbacks when compared with the Finsen treatment. Firstly, statistics of results are in favour of the Finsen treatment. As *Leredde* has pointed out, the value of X-ray treatment has not been studied in a systematic manner. Some authors have obtained good results, while others have been disappointed. With regard to Finsen's treatment, the reports are more satisfactory, but even here it is doubtful whether the cases of cure are as numerous, as complete, and as durable as is generally supposed. Our own experience at the Broca Hospital does not lend itself to any great optimism on this point.

It is true that phototherapy is very imperfectly carried out in France, because we do not attach sufficient importance to those minute details which exercise so great an influence on the result.

Phototherapy is much easier of application than radiotherapy. With the latter there is always danger of serious burns, whereas with the former the chances of accident are practically nil. 'Radiotherapy,' says *Professor Rieder* of Munich, 'is much more difficult to manage than phototherapy; it requires consummate skill in the operator, and demands a number of minute precautions. The patient should always be warned of the accidental consequences which may possibly follow its use. The dose must be prudently regulated, and the exposure stopped at the precise moment when its longer continuation would be hurtful, a task which is rendered still more difficult by the period of latency which intervenes between the irradiation and the appearance of reaction.

'It is true that an improved technique now enables us, for the most part, to limit the degree of reaction, and to avoid the occurrence of ulceration and sloughing. The difference of opinion on the question of curative reaction shows that the treatment is still in its infancy, and it cannot as yet claim any great superiority over the method of phototherapy.

'Radiotherapy should be reserved for those cases of lupus in which the situation, the extent, or the severity of the lesions prevent the application of Finsen's treatment. It is also indicated

in those cases which have already resisted phototherapeutic treatment. Probably rapidly-spreading cases, which are not very amenable to phototherapy, might also be treated more satisfactorily by the X-rays. When we have had further experience, and the technique has been improved, it is possible that radiotherapy may revolutionize the treatment of lupus, and prove itself equal, and even superior, to phototherapy.'

Histology.—Many investigators have studied the microscopic appearance of lupus after irradiation, and have endeavoured to establish the pathogenesis of its cure.

Himmel has observed the following appearances in sections of lupus nodules: 'A thin layer of epithelium limited an apparently homogeneous mass of a diameter equal to that of the lupus nodules. The outline of the epithelial cells could not be clearly made out, and the chorion was apparently retracted. The connective-tissue fibres were thickened and transparent, and crowded together. No elastic fibres could be distinguished. In stained sections, the connective-tissue cells were retracted and faintly coloured, showing still more alteration in the vicinity of the smaller lupus nodules. The giant cells were smaller than usual, with here and there a small, badly-stained nucleus.

'The epithelial cells were reduced to a fourth or a fifth of their normal size, and were of unusual form—retracted, homogeneous, containing a nucleus which stained very imperfectly. The leucocytes were heaped together in shapeless masses, and the boundaries of different cells could not be made out on account of their being so closely crowded together. In short, the microscopical examination showed that the superficial layers of the skin, the epithelium, a part of the dermis, and the lupus nodules themselves, were undergoing a process of progressive degeneration and necrosis.'

Hueter found that the primitive lupus tissue underwent a transformation into fibrous tissue, only a few groups of tuberculous cells remaining. The giant cells, the number of which was very marked, were chiefly situated at the periphery. Some nodules seemed to be composed exclusively of giant cells. The zone of leucocytes at the periphery of the tuberculous foci was much diminished or entirely absent, thus leaving the latter closely surrounded by a layer of connective-tissue cells. The limit of the tubercles was, however, always sharply defined. No tubercle bacilli could be detected.

Grouven demonstrated a considerable proliferation of connective tissue, forming a thick capsule around the tubercles. Under a low power this may be seen to be prolonged into the interior of the tubercles as a network with narrow meshes surrounding the débris of the lupus infiltration. Fusiform cells in abundance indicated an active growth of new connective tissue. Under a higher power, the epithelial and lymphatic cells were seen to be undergoing degeneration, which was manifested by a diminution in the nuclear staining, the breaking up of the nucleus, and the production of vacuoles in the cellular protoplasm. Similar alterations have been described by *Gassmann* as occurring in the walls of vessels which have been injured by radiodermatitis. He considers the primary phenomenon to be hyperæmia, leucocytic migration, and the formation of new connective tissue, which in its turn determines the destruction of the lupus nodules as a secondary result.

Doutrelepont examined sections from a case of hypertrophic lupus of the cheek, which had been treated by X-rays for a period of ten weeks. Under a low power the tubercle is seen to be surrounded by a mass of leucocytes, and is replaced almost entirely by connective tissue containing a few lupoid cells, with an occasional giant cell.

In a preparation stained by Gieson's method, an abundant proliferation of the connective tissue is noticeable. The lupus nodules are encapsuled, and tracks of connective tissue penetrate to their centre, forming a close network around the débris of the lupus infiltration. A preparation stained by Weigert's method shows that these latter are not intact. There is a degeneration of the lymphatic and epithelioid cells, which is shown by vacuolation so pronounced as to give the preparation the appearance of a sieve.

The following is apparently the mechanism of cure by radiotherapy: The hyperæmia set up by the X-rays provokes an abundant migration of leucocytes from the vessels. As may be seen after a tuberculine injection, the leucocytic infiltration commences at the periphery of the tubercular focus, and penetrates by narrow tracks into the substance of the lupus nodules, being ultimately transformed into fusiform cells and fibrous connective tissue. The presence of these fusiform cells bears witness to the active proliferation of the connective tissue. The lupus cells degenerate by vacuolisation; the nuclei lose their affinity for stains,

necrose, and become absorbed, the diseased tissue being replaced by cicatricial growth.

In *Gocht's* opinion, it is the superficial inflammation following irradiation that causes the destruction of the tubercle bacilli and the consequent cure of the disease. In support of this theory, he adduces the frequent improvement of a lupus patch after an eruption of erysipelas.

Kümmel does not recognise any specific action of the X-rays on lupus, but considers that the cure results from an electro-chemical or tropho-neurotic effect. On the other hand, *Albers-Schönberg* admits the possibility of a direct action of the rays on the tubercular tissue, which might possibly be assisted by a slight hyperæmia. He denies absolutely the utility of a violent dermatitis.

Scholtz has carefully studied the histological modifications which lupoid tissue undergoes during a course of radiotherapeutic treatment. In opposition to *Grouven*, *Doutrelepont* and *Gocht*, he believes that the primary phenomenon is the degeneration of the lupus cells, and that the hyperæmia and leucocytic migrations are due to secondary inflammatory changes.

He examined fifteen lupus foci, removed from eight different patients. Most of these presented identical appearances, so that we need only describe one series of specimens. They are from the same lupus focus at different stages of the reaction after irradiation —*i.e.*, at the beginning of reaction, during sloughing, and after cicatrization.

'The patch of lupus was situated on the chest; the skin was considerably infiltrated, thickly set with minute nodules, and covered with small crusts.'

'The treatment was as follows: From February 8 to March 7 ten exposures were given, of eight to eighteen minutes' duration, at a distance of 35 centimetres. The irradiations were calculated to produce violent dermatitis after a few weeks, followed by a superficial necrosis.

On March 17 the patch was red and œdematous; the redness continued for eight days. Phlyctenulæ made their appearance at the centre of the patch. A small portion near the edge was excised.

'On microscopic examination, the epithelium appears degenerated and homogeneous. There are a number of phlyctenulæ on the surface of the skin, which is infiltrated with leucocytes and pus

cells, especially in the neighbourhood of the tubercles. Most of the nodules have been absorbed. In their place we find a number of giant cells of abnormal size, some mononuclear cells with swollen and diffused protoplasm, and a large quantity of mononuclear and polynuclear leucocytes. The giant cells are 100 to 200 μ in diameter, and contain a number of nuclei. They are badly defined, and seem more like irregular diffuse masses of protoplasm enclosing a number of nuclei with faint outlines.

'The epithelial cells themselves are altered in appearance and badly defined, and frequently contain several nuclei. Their outlines run into one another, so that the nuclei appear to be situated in a homogeneous mass of protoplasm.

'A second section was made from a piece of skin excised from the same patch on March 25, when the lesion was superficially necrosed. The slough presents the same structure as that described above. The nodules have undergone the same changes, but they are more accentuated. The destruction and absorption of the lupus nodules, their penetration by leucocytic invasion, and the degeneration of the giant cells and epithelial cells, have all progressed a stage further. The leucocytes appear to play a preponderating rôle in the destruction of the lupus cells.

'The third biopsy was made after cicatrization at the edge of the lesion, where a few doubtful nodules remained. The epithelium consists of two or three layers, forming a straight line on the surface of the dermis, without any interpapillary prolongations. The epithelial cells themselves present modifications similar to those already described; there is but little cellular infiltration of the dermis, and the fibrous bundles of connective tissue are delicate, well stained, and parallel to the surface of the skin. Here and there a few traces of the lupus nodules remain, in the shape of protoplasmic débris, with numerous nuclei. In some instances this nodular débris is surrounded and penetrated by leucocytes, whereas in other situations it is limited and encapsuled by newly-formed connective-tissue fibres.' From histological examination, as well as from clinical experience, *Scholtz* concludes that in lupus tissue, as in the normal skin, the X-rays set up a process of degeneration of the cellular elements, and particularly of the giant cells, the epithelium, and the nuclei of the lupus itself, and that the phenomena of inflammation are the direct result of the degenerative process.

This is in accord with *Neisser's* hypothesis, which makes the inflammatory phenomena follow as a consequence of the primary alteration of the tissue, and also supports *Weigert's* conclusion that in the degeneration of reaction a modification of the tissues precedes the inflammatory symptoms.

We may therefore conclude that the cure of lupus—that is to say, the disappearance of the nodules and the destruction of the bacilli—is consecutive to the hyperæmia and inflammation of reaction.

As *Scholtz* has shown, all idea of a bactericidal action falls to the ground. The most important point in the cure of lupus is the localization of the inflammatory reaction, and its concentration exactly at the diseased point, in consequence of the degeneration of the lupus nodules themselves.

As *Scholtz* and *Neisser* have pointed out, there is in this respect a resemblance between the action of the X-rays and that of tuberculine, which also sets up inflammatory phenomena which are concentrated on the tuberculous nodules. The reactions to the X-rays and to tuberculine differ, however, in their further development. After an injection of tuberculine there is no necrosis or degeneration of the lupus foci, but only an ephemeral reaction, which is probably purely inflammatory. After X-rays the inflammatory reaction is of much longer duration, in consequence of the degenerative processes set up in the lupus nodules.

Conclusions.—It is impossible to say with certainty whether the cures following X-ray treatment are permanent. Recurrences are frequent after surgical treatment, and still more often after phototherapy. It will probably prove to be the same with radiotherapy. If *Kaposi's* theory is correct, a recurrence must be expected in all cases where the lesion has been cured by physical agencies. 'These,' he says, 'cannot produce a cure, but only set up inflammatory reaction, due to paresis of the bloodvessels. The absorption of any infiltration which has not been organized follows in consequence of the increase in the lymph-stream.' In his opinion cauterization or extirpation is the only radical cure, since there will always remain some débris of the morbid focus capable of producing a recurrence.

Thurstan Holland is also of opinion that in lupus the cure may be more or less durable, but is rarely permanent. In a case of lupus of the face cured in 1899, a recurrence occurred after two

years' interval. This, however, disappeared after a second series of irradiations.

On the other hand, many operators have obtained results dating many years back, without any trace of recurrence.

In conclusion, we may say that radiotherapy is not wholly satisfactory in the treatment of lupus, and that at present our results are not so conclusive as to make us prefer this method to the exclusion of all others.

It appears to be indicated in severe cases, in those which are widespread with much infiltration, whether ulcerated or not, and in those cases where other methods have failed. Sclerotic lupus is especially amenable to this treatment.

The irradiations should be given with greater or less intensity, according to the gravity of the lesions and the leisure of the patient, and severe radiodermatitis should usually be avoided.

A moderate hyperæmia gives results which are perhaps not so rapid, but which are much less disagreeable to the patient. Each case should be treated by the method best adapted for its cure, but we strongly advise the avoidance of superficial sloughing.

Radiotherapy and phototherapy may often be employed in succession in the treatment of the same case, in order to obtain a permanent result.

Case I. — Mme. G., aged twenty-eight. Lupus of the right elbow of four years' duration. Has been treated by permanganate of potash without success. The patch, of the size of the hand, has an unhealthy appearance.

January 21.—Dose, 5 H.; penetration, No. 5.

January 22.—Dose, 5 H.; penetration, No. 5.

February 3.—Sharp reaction and redness over the whole irradiated area; the epidermis is beginning to be shed. The patient complains of acute pain. The lesion is dressed with linimentum calcis.

February 9.—The epidermis is shed, the bare surface is red and weeping, and the nodules have almost disappeared. The pain is less violent. There is no sign of sloughing.

April 26.—Cicatrization is almost completed. A small ulcerated spot, the size of a sixpence, remains. The new skin is thin and atrophic, but without any lupus nodules. The ulcerated patch still looks unhealthy. Another dose of 5 H. is administered.

June 1.—The whole surface is much improved, but cicatrization is not yet complete. There are hardly any nodules remaining.

Lupus patches on the back of the hand and on the face were likewise greatly improved by moderate doses of 5 H., without the production of any considerable reaction.

The patient is not yet entirely cured.

Lupus Erythematosus.

We may discuss the treatment of lupus erythematosus here, as it is usually classed with lupus vulgaris, although it is not one of those dermatoses which are caused by a specific micro-organism.

Radiotherapy has not given very encouraging results in the treatment of this disease, and the cures which have been reported are by no means conclusive.

In 1898 *Schiff* and *Freund* treated a patient suffering from a lupus erythematosus of the face of the usual bat-like form. The left side was treated with X-rays, while the right side was left untreated. The irradiated area became dark red in colour, and the scales were more easily detached. The edges were flattened, and spots of a deeper red, of the size of a lentil, appeared on the surface. Gradually the infiltration disappeared, and the skin became smooth and normal. A zone of pigmentation surrounded the diseased area.

Jutassy has obtained a cure in a case of lupus erythematosus of the nose and face.

R. F. Woods also treated a similar case successfully. It was of four years' duration, and was situated on the cheek. Five exposures of ten minutes each, repeated twice a week, were sufficient to complete the cure.

Dr. James Startin also reports the cure of a case of lupus erythematosus of the nose and cheeks occurring in a young woman of thirty years of age. Six irradiations resulted in a complete cure, although a long course of treatment by external applications had been unsuccessful.

J. A. Lee reports a case of lupus erythematosus of the nose of four years' duration, which was greatly ameliorated by radiotherapy. Eleven séances of ten to fifteen minutes' duration were given, which resulted in a slight degree of reaction. In January, 1901, *Oudin* presented to the Société de Dermatologie notes on a female patient, twenty-nine years of age, who had a small patch of lupus erythematosus on each cheek. The case had been treated without success by *Fournier*, *Anderson*, and *Crocker*, and had also been subjected to high-frequency currents at the suggestion of *Dr. Brocq*, without any amelioration. *Oudin* gave

the patient a series of X-ray irradiations from June 20 to July 12.

June 20, first séance	...	thirty seconds.
,, 21, second séance	...	one minute.
,, 22, third séance	...	one and a half minutes.

On June 23 the amelioration was considerable. The patch was flattened, and had almost entirely disappeared by the next day.

The séances were then interrupted for a time, and recommenced later on. A total of eight or nine séances was given, lasting from one to one and a half minutes each.

The electric constants were as follows: A Rochefort coil was used, giving a 10-inch spark, with a current of 4 ampères at a pressure of 18 volts, and a break frequency of 20 interruptions per second. A Villard focus-tube with an equivalent spark of 4 inches was employed, and the distance of the tube from the skin was 3 centimetres.

On August 5, when the patient was again examined, the lesion was found to be completely cured.

These results are somewhat surprising, considering the short time—five or six days—in which the lesions disappeared, whereas an ordinary reaction usually requires at least eight or ten days.

Instead of moderate exposures, *Scholtz* has employed energetic irradiations with good success. Phlyctenulæ, excoriation, and slight necrosis ensued, but they all speedily disappeared, and the lesion healed, leaving a healthy scar. The cosmetic effect of the treatment was very satisfactory. After the lapse of a few months, however, a recurrence made its appearance on the site of the old lesion.

Scholtz then essayed another method, and gave some of his cases a treatment of a month's duration, employing feeble irradiations frequently repeated. One of these cases was eventually cured, but only time will show if the results are permanent.

Sjögren and *Sederholm* set up violent irritation, with redness, exudation, and the formation of crusts. On the subsidence of the reaction, the crusts fall off, leaving a smooth, slightly-reddened skin, from which the glandular orifices have disappeared.

Ullmann recommends a dose not exceeding 3 H. or 4 H. on each occasion, with an interval between the exposures long enough to prevent the occurrence of ulcerative reaction.

Freund considers that ulcerative reaction should be avoided. He has had some good results, but the treatment often requires to be repeated on account of the frequency of recurrence. *Schiff*, *Taylor*, *Hahn*, *Neumann*, *Grouven*, *Llaberia*, and *Lion* have had the like experience.

Freund believes that it is possible to insure a permanent cure if the treatment is continued long enough. The cicatrix is smooth, white, and level with the surrounding skin. In some cases, however, the X-rays appear to aggravate the disease.

Gron has treated three cases of lupus erythematosus. In one of these a cure was rapidly effected, in one there was some improvement, and one was aggravated.

Kaposi considers that the favourable action of the X-rays is due to their producing hyperæmia of the tissues and degeneration of the inflammatory elements.

It will be seen from the above reports how difficult it is to estimate the true value of radiotherapy in lupus erythematosus, and to decide what quality of rays should be employed in its treatment.

In *Kienböck's* opinion, heavy doses are required. If a cure is obtained, it is only as the result of a violent reaction and consecutive cutaneous atrophy.

From our own experience, we quite agree with this view. We endeavoured to set up a sharp reaction. It is sometimes impossible to avoid overstepping the desired degree in consequence of an unsuspected sensibility of the skin. Under these circumstances an erythema has succeeded of a deep reddish-violet colour, followed by vesiculation, weeping, and desquamation. Reparation soon set in, leaving a new skin, slightly atrophic in character, but apparently free from disease. After a time, however, in those places where the inflammatory reaction was least violent, new lesions appeared like those of the original disease.

We had no better success in a case of *Dr. Béclère's* which we treated at St. Antoine. It was an early case of lupus erythematosus involving the root of the nose. We gave moderate exposures of 3 H., but were unable to prevent the extension of the lesion. Subsequently *Dr. Béclère* treated the patient at his own house, and got better results by more energetic methods.

A patient sent by *Dr. Thibierge* was greatly benefited, but not cured. This case, however, the most favourable which we have

met with, is not conclusive. The patient was enceinte, and it is not unusual to see lupus erythematosus diminish or even disappear during the course of gestation. In another case, still under treatment, the lesions which have been irradiated are almost healed.

We give doses of 5 H. and 7 H., in one or two séances, using rays of a moderate degree of penetration. It should be remembered that in this disease the skin is very sensitive to the action of the rays, and is apt to react violently. A dose of 8 H. should not be exceeded without warning the patient of the reaction which may follow. The length of the interval required depends on the condition of the skin, and is usually from fifteen to twenty days.

In this most obstinate disease the X-rays do not seem to give any better results than other modes of treatment. Those forms of lupus erythematosus which are modified by ordinary means are also amenable to radiotherapy, with which we get more rapid, if not more durable, results. The more inveterate varieties do not improve without violent reaction, and even then the improvement is not always permanent.

Lepra.

In a certain number of cases the X-rays have been successfully applied to the treatment of leprosy.

In 1901 *Sequiera* reported a case of tuberculated lepra which was superficially ameliorated by radiotherapeutic treatment, the nodosities becoming softer, and in some instances disappearing.

De la Camp has not met with any success in the treatment of these cases by X-rays.

Scholtz has also treated two cases of leprosy without success. He was able to make a histological examination under the following conditions:

'In order to determine the modifications following the treatment by X-rays, a small space in the centre of a nodule was irradiated. Six exposures were given, of ten minutes each, at a distance of 6 inches.

'An erythema of the irradiated area followed, with no apparent result except a slight diminution of the nodules.

'Five weeks after the exposure, the nodule was excised. Under the microscope the infiltration due to the disease was slightly less noticeable in the parts which had been irradiated. Bacilli were present in great numbers; they stained readily, but appeared

rather more granular than elsewhere. The X-rays had apparently produced no injurious effect on their vitality.'

In 1902 *Oudin* presented to the French Electrotherapeutic Society two cases of tuberculated lepra treated by radiotherapy. 'The X-rays,' he says, 'seem to have a specific action on morbid tissues, gradually causing their disappearance, without influencing the integrity of the healthy tissue in their neighbourhood. The reaction should not be allowed to pass the stage of erythema.

'The patients I have treated are far from being cured, and I cannot recommend radiotherapy as the ideal treatment for lepra; but undoubtedly where they have been irradiated the lesions have undergone retrogression.

'Is the action of the rays microbicidal, vasomotor, or trophoneurotic?

'It is difficult to frame any hypothesis on the subject, in consequence of the complex character of the lesions, and the existence of nervous and vascular alterations caused by the micro-organisms.'

As regards technique, it is the same as that used in mycosis fungoides. Each diseased area should be made to absorb a dose of 5 H. or 6 H.—*i.e.*, the largest quantity of rays which is compatible with the integrity of the skin. This is the method we should adopt if a case of leprosy should come under our care.

CHAPTER VII

RESOLVENT ACTION OF THE X-RAYS ON NEW GROWTHS OF CONNECTIVE TISSUE

Scleroderma.

We have treated two cases of circumscribed scleroderma by radiotherapy. Our results, without being conclusive, are of some interest, as they are in accordance with those published by *Barney* in America.

The two female patients under our care suffered from long-standing lesions of a very obstinate character. The patches of scleroderma were well localized, and had existed in one case for two years and a half, and in the other case for three years. All the usual therapeutic measures had been tried in vain, and electrolytic treatment had not resulted in any sensible amelioration. Both cases were submitted to radiotherapeutic treatment. The regions irradiated included a margin a centimetre in breadth round each lesion, while the healthy skin beyond this was protected by a lead shield. An average dose of 5 H. to 8 H. was given, with rays of penetration No. 5. No great reaction resulted, the redness being hardly visible. At the end of fifteen to twenty days there was a certain amount of pigmentation, which was darker around the edges of the patches. At the same time the irradiated skin lost its smooth and shining appearance, and became softer.

A second irradiation was given three weeks after the first. This was followed by slight erythema and itching. The skin desquamated, leaving a new superficial layer of more healthy appearance, and showing a rose-red colour in places, in lieu of its former white and atrophic appearance. The skin appeared less tense, and here and there finely-crossed striæ made their appearance.

These phenomena were unaccompanied by any visible reaction,

with the exception of a slight transitory erythema and a peripheral pigmentation, which in some cases extended to the centre of the irradiated areas. All the patients were benefited by a continuance of the treatment, consisting of a dose of 6 H. or 7 H. every three weeks.

From the absence of all inflammatory reaction, we may conclude that a patch of skin affected with scleroderma is less sensitive to the X-rays than normal skin.

None of the cases are completely cured, but the lesions are of less extent, the skin is altered both in texture and in appearance, and we look forward to a complete recovery in time.

One of the patients, who was seen again in October last, was completely cured.

The treatment demands a great expenditure of time. Some of the cases which have shown improvement have already had seven or eight séances at intervals of three weeks. Electrolytic treatment, however, is equally tedious, and the results are not in any way better. Moreover, the treatment by radiotherapy is painless, whereas electrolytic treatment is very disagreeable in spite of the comparative insensitiveness of the patches of scleroderma.

What is the *rationale* of this action? May it not be due to a stimulation of the normal elements of the integument, to the detriment of the new formation?

It is well known that some patches of scleroderma are cured spontaneously, so that we should be cautious in attributing any amelioration to the influence of the X-rays alone. It may be noted, however, that the lesions which are most improved are those which have been energetically treated, whereas those which have not been irradiated are not modified in appearance.

We may draw attention to the fact that in all our cases the affection consisted of well-localized patches of morphœa.

The treatment would be more difficult, if not impossible, in cases of diffuse scleroderma, although even in these cases a certain amount of improvement might occur.

We agree with *M. E. Pfahler*, that in scleroderma the results of X-ray treatment are but small in comparison with the time and energy expended.

Case I.—R., aged twenty-four. Scleroderma of two and a half years' duration. Localized patches on the chin and below the right ear. Has been treated by electrolysis and high-frequency currents without result.

The patch below the ear is of typical appearance, white and atrophic, and measures 3 centimetres by 1 centimetre. It is treated by radiotherapy, using rays of penetration No. 5 or 6.

January 8, 1904.—Séance of twenty-five minutes ; distance, 12 centimetres ; quantity, 7 H.

January 25.—No marked erythema, but a slight amount of pigmentation. The patient thinks the patch is softer.

Irradiation of twenty-five minutes on the same patch. The quantity absorbed is about 7 H.

February 11.—A certain amount of redness and itching followed the last exposure. The skin has desquamated without any great reaction, and the new skin looks more healthy, softer, more vascular, and not so atrophic.

A dose of 6 H. is given with an exposure of twenty-five minutes.

March 4, 1904.—The lesion is improved. Two exposures are given on consecutive days, the first of fifteen minutes' duration, and the second of ten minutes', the total quantity being 6 H. or 7 H.

March 22.—The appearance is satisfactory, but without any great alteration. A dose of 6 H. or 7 H. is given in a séance of twenty minutes, using the static machine.

March 23.—The patch on the chin is treated with a dose of 7 H. during an exposure of twenty minutes.

April 12.—Slight reaction on the chin. The patch below the ear is irradiated with dose of 7 H.

The lesion on the chin is not so much improved as that below the ear, which is less atrophic, and, in the patient's opinion, has never been in so satisfactory a condition.

Case II.—Mme. Henriette, aged 24. Scleroderma on the abdomen of three years' duration, which has been treated by thyroid extract and other methods without success.

There are three patches—one on the left flank, one on the right flank, and a third smaller one in Scarpa's triangle on the right side.

November 23, 1903.—The left flank is irradiated for fifteen minutes with rays of penetration No. 5, the equivalent spark being 2½ centimetres in length.

November 26.—A second similar exposure is given, bringing up the total quantity to 7 H. or 8 H.

December 15.—There has been no pain ; the irradiated patches are softer and less atrophic. The surface is covered with fine hatched lines. The skin around the patches is pigmented.

An exposure of fifteen minutes is given on this and the following day, bringing up the whole amount to 7 H. or 8 H.

January 19.—The patch on the right thigh has improved. The patch on the right flank is exposed to two irradiations of fifteen minutes each, with a total quantity of 8 H.

February 5.—There is marked pigmentation of the right flank. On the left flank there is some improvement, but a certain amount of reaction still persists. Two exposures are given to the left flank of fifteen minutes each, notwithstanding the persistence of pigmentation.

February 23.—Pronounced pigmentation of the right flank. The improvement is stationary.

The left flank is red. There is an equal degree of pigmentation in the diseased area and on the healthy skin. The lesion is somewhat smaller.

On the right flank the skin is more flexible.

An exposure of 6 H. or 7 H. is given to the patch on the right flank.

March 8.—A similar irradiation is given to the left flank.

March 26.—An irradiation of 8 H. of twenty-five minutes' duration on the right flank.

All the lesions which have been treated are more or less ameliorated, but none of them are completely cured.

Keloid.

One of the first successes of the X-rays in cases of keloid was that by *M. L. Herschell Harris*, reported by *Williams* in 'The Roentgen Rays in Medicine and Surgery.' The keloid followed a surgical operation for tuberculous glands. The treatment was completely successful.

Barney treated a stubborn case which had recurred three times after surgical operation, with complete success.

Dr. Fordyce considers that radiotherapy is useful in the treatment of this disease, while *Fox*, *Varney*, and *W. L. Heeve* have also reported successful cases.

Taylor has seen the X-rays produce notable softening of a cicatrix resulting from a severe burn. Finally, early in 1904 some favourable results were reported by *Bisserié* to the Société de Dermatologie. At the Broca Hospital we have treated four patients with good results.

A violent reaction is to be avoided, and we seldom exceed a dose of 6 H. or 7 H. at each irradiation. The exposure may be repeated every fifteen or twenty days, according to the state of the integuments.

The keloid begins to soften and diminish after the second or third séance, the surface becoming rose coloured, with a slight amount of pigmentation.

In one case, where the lesion was of no great extent, we obtained an amelioration almost amounting to a cure. The patient had a severe burn on the cheek as a consequence of excessive exposure to the Finsen light. The keloid disappeared after treatment with X-rays, and at the present time its situation is hardly visible.

In another case a considerable degree of amelioration has been

obtained. This was an enormous keloid which formed on the scar of a wound made by a knife, and extended from the cheek to the ear. More than half the lesion disappeared under the treatment. The remaining portion is soft, and we hope to see further improvement. Six applications, with a medium dose of 6 H. or 7 H. at each séance, were given during a period of five months. The neighbouring skin was protected by a lead shield which exactly fitted the diseased area, and no severe reaction resulted.

Electrolysis had been previously tried, with the result that the lesion became still more noticeable in consequence of the cicatrices left by the needles. In any case, treatment by electrolysis would have been much more tedious. In our opinion this should be used only in lesions of limited extent, whereas radiotherapy should be reserved for the treatment of those giant keloids which are occasionally met with. The treatment is not infallible, but usually gives very satisfactory results.

Case I.—Mme. B., twenty-five years of age. Two years ago she received a cut with a knife, which extended from the labial commissure to the back of the ear. A keloid appeared on the scar, commencing 3 centimetres from the mouth and extending as far as the lobe of the ear, where it divides into a number of branches. The lesion projects about half a centimetre above the surface of the skin.

Electrolysis, high frequency, and other treatment have produced no appreciable result. A cast of the lesion was made, and from this an aperture was cut in a sheet of lead, so as to leave the keloid bare, while protecting the surrounding skin.

November 27, 1903, *to April* 28, 1904.—The patient has received six series of exposures. During each series the lesion has absorbed 6 H. or 7 H., thus giving a total dose of 40 H. We were careful not to set up any reaction other than a slight erythema, the patient being anxious to avoid all redness, as she could not remain confined to the house.

May 28.—The keloid has diminished to a quarter of its former size, and in some parts under the ear is no longer visible.

The patient is still under treatment, and we hope to produce a favourable result.

Case II.—Mdlle. R., aged twenty-two. The patient has a small keloid on the right cheek, which is slightly raised above the surface of the skin, and is of the size of a sixpence.

It was the result of a prolonged exposure to a lamp of the Broca-Chatin model during a course of phototherapy for lupus of the cheek.

From November 30, 1903, to January 22, 1904, she had three irradiations, with an average dose of 3 H. or 4 H. on each occasion.

January 6.—After two exposures with a fortnight's interval, a phlyctenula appeared, followed by the formation of crusts.

February 5.—The last exposure was given on January 22. The keloid is hardly visible. The skin is soft, with merely a slight atrophic aspect, scarcely contrasting with the appearance of the face.

Case III.—Mme. V., aged fifty. The patient has a keloid on the dorsum of the nose, following destruction of an epithelioma by the actual cautery. Nothing is to be seen but the keloid, but we suspect there may be a recurrence of the disease underneath.

March 11, 1904.—Rays of quality No. 5 ; dose absorbed, 8 H.

March 31.—Considerable redness resulted, but this is now abating. The itching, which was very severe before the treatment, has ceased. The keloid is diminished in size.

A fresh exposure is given : dose, 5 H.

April 19.—Sharp reaction, with considerable redness and a small ulceration, the size of a lentil, in the centre of the lesion.

April 28.—The lesion is cicatrized. Another exposure is given of 4 H.

May 19.—A slight amount of redness still remains ; the keloid has almost disappeared, leaving a soft smooth cicatrix, which is hardly visible.

The patient is still kept under observation.

Sarcoma—Melano-Sarcoma.

But few cases of sarcoma have been treated with the X-rays, and observers are far from being agreed as to the success of the treatment.

For the last few years radiotherapy has been used in America for the treatment of sarcoma, but it does not seem to have met with the same amount of success as in the case of epithelioma.

Turnure, at the Columbia College, New York, has employed the X-rays in the treatment of this disease. The amelioration was only temporary, and the neoplasm continued to increase after a temporary arrest of growth. *Varney* also considers the rays to be merely palliative in their action.

Coley considers radiotherapy to be useful, and *W. Newcomb* agrees with him, while noting that complications and metastasis sometimes occur.

In 1902 *Pusey* published particulars of a case which was greatly improved by the use of X-rays. The case was a small round-celled sarcoma, which commenced at the angle of the jaw, and had invaded the neck on both sides. One side was treated by operation, and the other by the X-rays. Rays of a very penetrating quality were employed, notwithstanding which a certain amount of dermatitis occurred. The tumour gradually diminished, and finally disappeared.

In 1904 an interesting discussion took place at the Medical Society of Vienna, apropos of a paper of *Kienböck's*. The patient was a female, thirty-eight years of age, who during the two preceding years had undergone several operations of the nasal fossæ for successive recurrences of sarcoma which had invaded the pharynx and maxillary sinus. A histological examination left no doubt as to the nature of the disease, and the patient was inoperable at the date when she first came under *Kienböck's* notice. From October 15, 1903, to January 19, 1904, she received fifteen irradiations, with intervals of a week between the séances. The condition of the patient was greatly improved: the roof of the palate was raised, the eyeballs had retroceded, the sensation of hearing had returned, and the patient was able to walk alone.

This is a most interesting result, although the patient was not completely cured. *Kienböck* hopes to get a satisfactory result by the use of a special apparatus, which will enable him to cause the X-rays to act directly on the nasal cavities.

The following is the opinion of this eminent specialist on the treatment of sarcoma by radiotherapy:

'There are certain forms of sarcoma—for instance, round-celled sarcomata or endotheliomata of the face, originating in the nasal or buccal cavities — which are particularly influenced by radiotherapy. After slight irradiation they diminish in volume, and disappear—at all events temporarily, and perhaps permanently. A moderate dose is given with rays of great penetration, and an exposure of two or three minutes at a distance of 30 centimetres. In melano-sarcoma radiotherapy has also yielded favourable results.

'Fortunately the cells of rapidly-growing neoplasms seem exceedingly sensitive to the Roentgen rays, small doses of which will produce degeneration and destruction of the cells of the neoplasm without producing irritation of the superjacent skin.

'We may hope that other morbid processes in the interior of the body may prove amenable to radiotherapy. The field is a wide one, and we trust it may be speedily investigated in a more thorough manner by future explorers.'

Following *Kienböck's* communication, *Grossmann* cited a similar case of sarcoma which was rapidly cured by this method. Unfortunately, there was a recurrence in the course of a few weeks, but

this appeared in a region which had not been irradiated, so that it does not negative the value of the treatment.

Holzknecht considers that sarcoma is more sensitive to the X-rays than epithelioma. This special sensitiveness facilitates the action of the rays on deeply-seated structures, as in sarcoma of the ovary, without injury to the superficial tissues. Deeply-seated epitheliomata are more refractory, and are not so readily affected without injury to the superjacent skin.

Freund does not agree with this view. In his opinion sarcoma is not so readily attacked by the X-rays. He cites a case of generalized cutaneous sarcoma which he treated for many weeks, without producing any effect.

According to *Morton*, sarcoma is acted on in the same manner as epithelioma, and under the same conditions. Two of his cases are reported in the *British Medical Journal* for April, 1904. One was cured; the other was improved, but was subsequently lost sight of. The X-rays act in all probability by obliterating the smaller bloodvessels, since the lesions are very vascular, and their development is dependent on an adequate supply of blood.

Reider also obtained good results with X-rays in a case of sarcoma of the left nostril.

Mertens reports the case of a girl of eleven years of age suffering from a sarcoma of the right scapula of nine months' duration. The tumour was of the size of the fist, with enlargement of the cervical and axillary glands. Ablation was attempted, but the operation had to be abandoned in consequence of collapse. The operation showed an invasion of the scapula and the subscapularis muscle. On microscopical examination the tumour proved to be a small-celled sarcoma.

After ten days a recurrence made its appearance, and radiotherapeutic treatment was begun four days later. A hard tube was used, and an exposure of six minutes was given once a day for a fortnight. Afterwards an exposure was given every other day.

The tumour began to diminish in size after six exposures, and on the tenth day it had entirely disappeared, while the cervical and axillary glands had disappeared by the fourteenth day. Twenty exposures in all were given, and at the end of the treatment only a small swollen ganglion remained at the posterior border of the sternomastoid muscle. Six weeks later there were no signs of recurrence.

The linear cicatrix due to the operation became thin and bluish in colour, and was markedly increased in breadth, thus showing that the X-rays can influence the newly-formed cells of cicatricial tissue.

In another case the author was not so successful. An acute dermatitis was set up, and the treatment had to be suspended; metastasis occurred, and the patient died.

Morelle considers that the results obtained by radiotherapy in the treatment of sarcoma are not so brilliant as those which have been reported in epithelioma. Surgical treatment is also unsatisfactory in these cases. He advises recourse to operation in cases of limited sarcoma. Where surgical intervention is contra-indicated on account of the multiplicity and extent of the lesions, he advises radiotherapy, combined with the subcutaneous injection of arsenic or toxins by Coley's method.

Ali Krogius has treated with the X-rays a man suffering from a large sarcoma of the scalp, involving the periosteum. In the year 1901 the patient had undergone an operation, which was incomplete. In 1903 a recurrence appeared, involving the occipital region, and a second operation was performed with but partial success. The microscope showed the usual elements of a round-celled sarcoma, in which were interspersed polymorphous cells and some giant sarcoma cells.

At the end of two months' treatment by radiotherapy the nodules had disappeared, and four months afterwards there were no signs of recurrence.

In 1904 *Brocq*, in a discussion at the Société de Dermatologie, maintained that radiotherapy shows its most marked effect in the treatment of soft sarcomata affecting the thorax.

Sabouraud also records a case in which the lesion began to disappear after the absorption of a quantity of X-rays equal to 16 H.

Leredde doubts whether these are true cures, or merely due to absorption of the œdema and shrinking of the cellular elements of the lesion. Careful histological examination can alone give an answer to this question, but *Sabouraud* points out that in this case even the microscope cannot give a definite answer.

Darier reported a case in which he performed a plastic operation after the apparent cure of an epithelioma by removal. He found evidence of epithelial growth, which had occurred since the removal

of the tumour. This histological recurrence had existed for more than four years without giving rise to any signs of clinical recurrence.

On June 10, 1904, *Dr. Béclère* presented to the Société Médicale des Hôpitaux a patient cured of a sarcoma of the superior maxilla, which had returned after two surgical operations. We reproduce here the notes of this case, with which he has kindly furnished us.

The case was one of malignant sarcoma, the diagnosis of which was made by *Piéry* and confirmed by *Professor Tripier.* The great vascularity and the character of the small round cells composing the tumour bore witness to its malignancy.

In consequence of the non-success of ordinary treatment, the patient was put under radiotherapy. This had already been begun at Chambéry, with encouraging results. Before each exposure a subcutaneous injection of quinine was given.

The patient was sent to *Dr. Béclère* by *Dr. Walther* on January 6, from which date an irradiation of 3 H. was given every week. On March 2, after nine exposures, the circumference of the affected cheek had diminished by 2 centimetres. After April 6 the exposures were given once a fortnight, and at the beginning of May the case might be considered cured.

On the last eleven occasions, half an hour before the séance commenced, the patient was injected with 3 grammes of bichloride of quinine.

'It is impossible to doubt,' says *Dr. Béclère*, 'that the disappearance of this tumour was due to the Roentgen rays, since the improvement commenced from the date of their first employment, whereas neither arsenic nor quinine had produced the slightest effect, though given in many forms and for a long period.'

It is a question whether the cure should be attributed to the rays alone or to these in combination with the quinine injections. With regard to this question *Béclère* says: 'The use of quinine injection as an adjunct to the rays was first introduced by *Morton* of New York. The question of the action of quinine on the neoplasm did not enter into consideration, the theoretic idea which guided *Dr. Morton* being a totally different one.'

'It is well known that reinforcing screens are used in order to lessen the time of exposure in radiography. The photographic plate is covered by a fluorescent screen—*i.e.*, one that emits visible radiations when exposed to the X-rays. By this means the pho-

tographic plate is more rapidly affected, or rather it is more forcibly impressed in the same space of time. *Dr. Morton's* idea was to introduce a sort of reinforcing screen into the tissues themselves. This he attempted to do by injecting into the blood a solution capable of fluorescing under the action of the rays. In this way the cellular elements would be exposed not only to the X-rays, but to luminous radiations, and the violet and ultra-violet rays which are produced by fluorescence. Various fluorescent substances might be used. *Morton* prefers bichloride of quinine, which he injects into the tissue half an hour or an hour before irradiation.

'It would seem that the commencement of the amelioration at Chambéry coincided with the time when the injections of quinine were used in combination with the rays, whereas the case remained stationary during the period when the X-rays were used alone. Looking at this case alone, I should be inclined to think that *Morton's* procedure was efficacious, but the results of other cases leave me in doubt.'

Béclère thus concludes :

'The specific and elective action of the Roentgen rays is shown equally well in sarcòma and in epithelioma. This selective action may be exercised on the neoplasm without injury to the healthy skin which covers it.'

Dr. Reboul of Nîmes communicated to the Congress of Grenoble a case of cystic sarcoma of the lower jaw, treated by radiotherapy after surgical intervention had failed. Cystic development had occurred in the skin and mucous membrane of the mouth. After some twelve exposures these entirely regained their normal appearance. In this case radiotherapy was used as a prophylactic measure, showing that surgeons are beginning to use the X-rays as a means of obviating recurrences after operation.

We have ourselves treated several cases of sarcoma with very satisfactory results.

In a case of primitive diffused sarcoma of the dorsal region, a few irradiations produced a complete disappearance of the tumours ; but we unfortunately lost sight of the patient, so that the case is not conclusive.

Another patient presented on the right thigh a number of reddish vascular tumours, which were raised, soft, and sarcomatous in character. The lesion was limited to the skin. We began the radiotherapeutic treatment with a dose of 9 H. or 10 H. This

produced a sharp reaction. When this had subsided, the tumours were found to be flattened and paler in colour. A second irradiation of less intensity was given. At the present time only a little redness remains, but the skin is not elevated, and although the case cannot be said to be cured, it is wonderfully improved. Analogous results were obtained in a sarcomatous lesion of the left thigh. There were in this instance no raised tumours, but the whole lower third of the thigh was invaded by a hard, red, infiltrated tissue, which on microscopic examination proved to be sarcomatous.

Moderate irradiations were given, and the improvement is most marked, although the patient is still under treatment.

At the present time we have under our care a woman who was operated upon by *Dr. Walther* for a sarcoma of the parotid, in which recurrence appeared six months afterwards. The case was inoperable. At her first visit we found four large hard tumours occupying the parotid, temporal, and auricular regions, together with the helix of the ear, all of which were adherent to the deeper structures. The diagnosis was one of chondro-sarcoma. The patient had already been treated by radiotherapy by two physicians, in spite of which the lesion was progressing and the pain was increasing in intensity. A dose of 9 H. was given in two successive séances. The patient returned in a fortnight. The tumours were modified, and the pain had abated. A second dose of 7 H. was given. A fortnight afterwards there was evidence of sharp reaction. In places the epidermis was separated, but in the patient's opinion the tumour had diminished by one half. Her general appearance was improved, and the skin of the face, which had been stretched by the tumour, had regained its flexibility in consequence of the subsidence of the sarcomatous elements.

After some time a new exposure was given, and the patient remains greatly improved, although not entirely cured. Her general health is much better, although her weight has not altered.

At the present time only a small swelling remains, which is still decreasing in volume, and everything points to its complete disappearance. The general health is good, and the pain has entirely ceased.

She is still under treatment, with an irradiation of 5 H. repeated once a week.

Bisserié has kindly sent us notes of two cases affected with melano-sarcoma. The first is that of a man with a melano-sarcoma

PLATE VI.

Before irradiation.

CUTANEOUS SARCOMA (CASE 1).

Photograph taken after absorption of 11 H. There are still traces of reaction, but the tumours have completely disappeared.

To face p. 328.

of the breast, with ulceration and cracks, with fœtid, sanious, and purulent discharge. The axillary glands are enlarged. The lesion was irradiated with rays of penetration Nos. 4 or 5, and a dose of 9 H was given. A fortnight afterwards a second exposure of similar intensity was given. A sharp reaction supervened; the edges of the tumour became less marked, and altered in consistence. After a time cicatrization commenced, and the axillary glands disappeared. Three months later there only remained a soft tumour of the consistence of a lipoma and of the size of a five-shilling piece. There were no signs of ulceration, and the pain had entirely disappeared. A fresh irradiation of 4 H. was given, and there is every prospect that the case will still further improve.

In the second case, that of a woman, an entirely different mode of treatment was followed by good results. The doses were much smaller and more frequent, and all reaction was sedulously avoided.

It would seem, therefore, that under similar circumstances sarcoma, or at all events certain forms of sarcoma, are affected more rapidly than epithelioma.

The following is the method of procedure. If the lesion is a serious one, it is well to proceed as rapidly as possible, giving the greatest quantity of X-rays compatible with the integrity of the integuments.

We may give a dose of 4 H. or 5 H. at a single sitting, with rays of penetration Nos. 8 or 9, and then wait a week before proceeding further. This is the procedure employed by *Dr. Béclère* at St. Antoine. It is an excellent method, to which there is only one objection—viz., that a second application is given before the inflammatory reaction due to the first exposure has entirely ceased. Hence, after two or three irradiations the skin becomes inflamed, and the treatment has to be intermitted.

The method which has given the best results in our hands is a similar one, with the exception that we increase the dose to 6 H. or 7 H., given in one or two consecutive sittings, according to the region affected and the state of the integuments, and that an interval of ten to fifteen days is allowed to elapse between successive irradiations.

If the lesion is a very serious one, and is extending rapidly, the dose of 7 H. may be increased, but dermatitis will usually follow. This dose of 7 H. should not be exceeded only in exceptional cases, where the gravity of the condition seems to demand it.

The reaction should be slight, consisting of erythema of a greater or less intensity, which should rarely pass on to superficial excoriation. Ulcerative radiodermatitis should in most cases be sedulously avoided, as it retards the progress of the treatment, and has no beneficial effect on the patient.

There is no need for alarm if a slight ulceration is produced, since this will rapidly heal.

The penetration of the rays should vary with the nature of the sarcoma, its situation, and its depth. Generally we employ rays of quality Nos. 7 and 8, while some authors recommend those correponding to Nos. 10 or 11 on Benoist's scale. We see no objection to the use of these more penetrating rays.

In cases of osteo-sarcoma, rays of penetration Nos. 9 or 10 should be used, and the skin may be covered with a sheet of aluminium foil to absorb the less penetrating rays. In this case the Holzknecht pastille should be placed below the metal foil.

We are convinced that in these cases, as in many others, massive doses should be used. In the case of chondro-sarcoma mentioned above, the patient had been treated without result by two different practitioners, who used exposures of only a few minutes' duration, repeated two or three times a week. Instead of showing signs of diminution, the lesion continued to increase in size. After he came under our care, two or three stronger exposures were sufficient to cause a wasting of the tumour, which decreased in volume by more than one-half. The improvement still continues, and there is every hope of a complete cure.

As regards the effect on the general health, in all the patients which we have treated the result has been excellent. In none of them have we noticed the slight toxæmia described by some authors; on the contrary, their appetite improved and their weight increased. They had neither vertigo nor fever, which, according to some observers, follows the reabsorption of the elements of the neoplasm. These symptoms are probably due to nervous impressions.

In conclusion, we may say that certain cases of sarcoma are rapidly ameliorated, and even cured, by the X-rays, so far as their objective symptoms are concerned. In other cases the disease resists treatment, and no results follow radiotherapy, except the diminution of pain.

To what is this difference due?

It is evident that lesions which are widespread, and invade the deeper structures, are not likely to be so favourably influenced as more superficial and localized disease. Apart, however, from size and position, there would appear to be fundamental differences in the manner in which lesions identical in appearance react to irradiation.

The cause of this difference must be sought in varieties of form and evolution which are but little understood. The group of the sarcomata includes a number of neoplasms with well-marked differences. We hope that histological examinations may throw some light on the subject, and enable us to give more precise indications for radiotherapeutic treatment. It is well known, however, how difficult, not to say impracticable, are these investigations.

We are far from giving radiotherapy the preference over surgical intervention in cases of sarcoma.

The growth should be surgically treated in all cases where the disease can be totally removed without excessive mutilation. Radiotherapeutic treatment should be begun a few days after operation, even before the completion of cicatrization, in order to avoid a recurrence of the growth. Slight exposures of 3 H. or 4 H. should be given in the course of a week, and this may be done without removing the dressings. The treatment should be continued once a fortnight for two months after the wound has completely healed.

At the smallest sign of recurrence, radiotherapeutic treatment should be commenced afresh.

In cases where surgical intervention is possible, but the extent of the disease prevents the complete removal of the affected tissues, an operation should still be performed, and this should be followed by careful radiotherapeutic treatment.

In operable cases radiotherapy may determine a complete cure, if the lesion is not too widely spread.

Even where a successful result is not obtainable, it will reduce the pain, and may even to a certain extent arrest the evolution of the disease. It is, at any rate, an excellent palliative treatment for relieving the sufferings of the patient.

Case I.—M. D., tailor, thirty-seven years of age. Sarcoma of the dorsal region that began five months ago by a small blue patch, which became violet and yellow in places and gradually increased in size. This was accompanied by considerable itching, and the lesion, which was flat at first, gradually

became raised above the surface of the skin until the relief could be felt by the finger.

The appearance of the lesion is shown in Plate VI. The tissues are hard and infiltrated, and the coloration is dark red, like wine lees.

October 20.—Rapid enlargement of the glands in the cervical, occipital, and axillary regions. Purpura of the neck.

The tumours, three distinct swellings, were irradiated separately.

December 29.—Duration, fifteen minutes; distance, 10 centimetres; rays, No. 6; dose, 4 H. or 5 H.

December 30.—Duration, ten minutes; distance, 10 centimetres; rays, No. 6; dose, 3 H.

January 12.—The tumours are smaller. Some infiltration of the skin remains. It is of a violet-red colour and covered with scales. The itching has ceased. The surface is quite flat and smooth, instead of being nodular as before. At the left lower margin of the irradiated area is a small tumour, about 1 centimetre in diameter. It has probably escaped the action of the rays, being at the periphery of the lesion and covered by the lead shield. This small area is irradiated for ten minutes with a dose of 3 H., the rest of the tumour being protected by a lead shield.

January 22.—The tumours have entirely disappeared, including the small one irradiated on the last occasion.

The skin is still violet-red in colour, but is no longer infiltrated.

The second photograph shows the diseased region at this date.

The patient has not since returned, although we had intended to treat the enormous concomitant adenopathy. This had not diminished, and was probably due to leukæmia.

CASE II.—Mme. V. G., aged forty-seven. Cutaneous sarcoma of the internal surface of the right thigh. The diagnosis was confirmed by histological examination. The lesion is 9 centimetres long and 5 centimetres broad, and of a reddish-violet colour. It is of soft consistency, and irregular in outline, and projects 6 or 7 millimetres above the surface of the skin. A similar lesion is to be seen on the lower part of the left leg, but this is of very different appearance.

February 11, 1904.—An irradiation of 9 H. is given to the right thigh with rays of No. 5 penetration.

March 1.—Bright red colour; a certain amount of itching; the tumour seems to be somewhat flattened.

March 18.—There are signs of considerable reaction. The epidermis is raised in phlyctenulæ, which break and give issue to a seropurulent fluid. The whole surface is covered with crusts, but the skin is less infiltrated.

April 28.—The reaction has abated. The lesion is modified in appearance, but still exists, with a certain amount of infiltration. An irradiation of 8 H. is given.

May 16.—Sharp reaction has occurred, which is now subsiding.

June 1.—The lesion appears cured. The redness has disappeared and the infiltration is hardly noticeable. The area previously occupied by the lesion is quite flat. A few scales still exist on the surface of the skin. All pain has ceased.

The left leg is also improved.

Lipoma—Dercum's Disease.

In July, 1904, *Boudet* presented to the Medical Society of Lyons a woman affected with Dercum's disease, in which numerous lipomata occurred and had been satisfactorily treated by the X-rays.

The case was a typical one of the disease, with soft, disseminated, painful tumours. The pain was exceptionally severe just before the appearance of the tumours, and warned the patient of the region where a tumour was about to form.

Various methods of treatment had been tried without much result, although some of the tumours had apparently diminished under the use of thyroid extract.

In March, 1904, *Nogier* began radiotherapeutic treatment on some of the larger tumours.

One of these, situated on the right arm, showed a diminution in circumference of 48 millimetres after fifteen exposures, with a total duration of 140 minutes.

Two others diminished considerably after thirteen exposures. During the two months the treatment lasted, the patient had lost 2 pounds in weight.

The result is remarkable, but as iodine was administered internally during the course of the X-ray treatment, the case is not by any means conclusive.

The author says: 'It is difficult to determine what *rôle* radiotherapy played in the amelioration which began during the administration of tincture of iodine, but was greatly increased when the X-rays were used. It may be that the improvement was due to the action of suggestion on a neurotic patient, but I do not think that this is the case.'

M. Béclère has had occasion to treat a patient suffering from the same affection. The results of the treatment were, however, not very brilliant.

The dose to be employed varies between 3 H. and 5 H. at each séance, and may be repeated every week. This dose might be increased to 7 H. or 8 H., when the interval should be also increased to twelve or fifteen days.

We have had no personal experience of this treatment.

CHAPTER VIII

RESOLVENT ACTION OF THE X-RAYS ON TUMOURS OF THE LYMPHATIC SYSTEM

The group of malignant tumours of the lymphatic system include many distinct varieties which are often not recognised clinically in consequence of the difficulty of diagnosis. In the works published on this subject it is doubtful if many of the cases correspond to the denomination under which they are reported. In many instances it is difficult to decide if a case with the typical symptoms of leukæmia is a true leukæmia or a lymphadenoma, and this is impossible unless a quantitative and qualitative examination of the blood has been made.

In the same way it is impossible to distinguish between a myelogenic and a lymphatic leukæmia without having recourse to a scientific investigation of the blood. We shall therefore adhere to the denominations used by the authors of the various reports under discussion, leaving to them the responsibility of the diagnosis.

We have already discussed the interesting researches made by *Heinecke.* He showed that lymphoid organs underwent special modifications under the influence of the X-rays, such as destruction of the lymphocytes, accumulation of masses of chromatin from the débris of the nuclei, and even the disappearance of the corpuscles of Malpighii from the spleen. These phenomena—destruction of lymphocytes and phagocytosis of their nuclei—are also observed in the lymphatic glands, even in the marrow of the bones, where a large portion of the specific elements is replaced by fat cells.

This specific action of the X-rays may set in rapidly after a very short exposure.

Hence we may hope that radiotherapy will yield good results in the treatment of affections characterized by proliferation of

lymphoid tissue, such as lympho-sarcoma, lymphadenoma, and leukæmia.

The reaction is rapid, and the séances should therefore be correspondingly short. According to *Heinecke*, the lymphocytes are speedily modified or destroyed by the X-rays without any effect on the superjacent skin.

We may now proceed to consider the results which have been obtained in the treatment of lympho-sarcoma, lymphadenoma, and leukæmia.

Lympho-sarcoma.

In 1903 *Williams*, in his work on radiotherapy, reported a case of lympho-sarcoma of the neck, which twice recurred after operation, and which subsequently yielded to radiotherapeutic treatment. Microscopical examination proved the case to be a round-celled lympho-sarcoma. Two photographs of the case, one before and one after treatment, are given, and these are quite conclusive as to its nature.

In June, 1904, *Bizard* and *Albert Weil* presented to the Société de Dermatologie a patient suffering from lympho-sarcoma. They had shown the case on a previous occasion in November, 1901. The cervical region and the upper part of the thorax was the seat of a number of tumours of a diffuse character, with adherent and infiltrated integument marked by large telangiectases.

The following is a report of the histological examination made by Gastou: 'Under a low power the sections show a network composed of thick bands of elastic fibres and connective tissue. Masses of cells disseminated through the interstices of this tissue occupy the deeper layers and the vicinity of the sweat-glands.'

No special alteration is to be noticed near the surface of the skin except that the epidermis is thinned, and the interdigitations have partly disappeared. The vessels are but slightly dilated. With a high power a reticulated tissue may be made out immediately beneath the epidermis, containing two distinct elements:

1. Plasma cells of considerable size, with large nuclei and abundant protoplasm.

2. Mast cells in layers parallel to the epidermis.

The plasma-like cells are chiefly perivascular, but can hardly be said to form a true infiltration round the vessels.

Here and there, in addition to the foregoing, masses of cells of

a special type are found grouped around the larger vessels and glands. They form well-defined nodules, with prolongations bounded by connective tissue. The cells themselves are of large size, having a basophile nucleus and clear and abundant protoplasm. Owing to mutual pressure, the cells are polygonal or irregularly rounded in form. In some cases a fine reticulum may be made out by staining with hæmato-eosin or picrocarmine.

It is difficult to decide to what category these cellular masses belong. They have a certain analogy with plasmon cells, but they differ from these in their regularity of form, in the presence of a central nucleus, and also in their reaction to staining.

They differ from syphilitis, tuberculosis, and other infective diseases in the mode of grouping of the cells. Notwithstanding the presence of a reticulum, they differ from mycosis in the way in which the cells are grouped around the vessels and glands, as also in the absence of epidermic infiltrations of the papillæ.

'The existence of a reticulum would seem to indicate an alteration of the lymphatic system, with localization of the cell masses around the vessels and glands. All the appearances agree with the supposition that the lesion is a lymph neoplasm, and this, together with the form and grouping of the sarcoma cells, forces us to the conclusion that the case is one of lympho-sarcoma.'

Darier also examined the specimens and confirmed the diagnosis of lympho-sarcoma.

From November, 1902, to March, 1904, the tumours increased, symptoms of compression made their appearance, and the patient suffered in general health. The authors therefore decided to try radiotherapy.

For a period of two months fractional doses were given with three irradiations per week. A total dose of 24 H. was absorbed during the first month, and 17 H. during the second month.

The treatment was carried out by *Albert Weil.* Under its influence the tumours diminished, the neck became smaller, the thorax resumed its normal appearance, and the general health improved. At the present time the case is completely cured, so far as objective symptoms are concerned.

The authors noticed that the patient exhibited manifest signs of toxæmia during the course of treatment, with sensations of fainting, shivering, etc., analogous to those noticed by *Skinner* during the radiotherapeutic treatment of cancer. They therefore

recommend fractional doses, in order to obviate the too rapid absorption of the elements of the neoplasm.

In opposition to this view, we may remark that the absorption of the pathological cells of the neoplasm has not been demonstrated; and further, that the toxæmic symptoms are so inconstant and evanescent that it may be doubted if they are really caused by the action of the X-rays.

At the congress at Grenoble *Professor J. Bergonié* communicated notes of a case of general lympho-sarcoma which had been greatly ameliorated by the X-rays.

The patient was of very cachectic appearance, and showed enormous ganglionic masses on either side of the neck, in the axillæ, and on the left side of the thorax, with great enlargement of the spleen. There was intense dyspnœa, and radioscopic examination showed that the lung was filled with a glandular mass, which had invaded the greater part of the thorax.

As *Dr. Béclère* observed, the *ensemble* of the symptoms pointed rather to a leukæmia; but an examination of the blood made by *Dr. Sabrazès* gave the following results:

Hæmoglobin	58 per cent.
Red corpuscles	4,947,000 per cub. mm.
White corpuscles	37,820 „
Polynuclear leucocytes ...	78 per cent.
Lymphocytes	11 „
Large lymphocytes	1·5 „
Large mononuclear cells ...	4 „
Eosinophile cells	10 „
Transitional forms	18 „
Free nuclei	10 „
Neutrophile myelocytes ...	10 „
Blood platelets	794,220 per cub. mm.

Time of coagulation slightly accelerated. Imperfect coagulation of the clot.

Inequality of volume and coloration of blood cells. Presence of polychromatic cells and granulated basophile cells. No red nucleated cells. Very slight iodophile reaction of some of the leucocytes.

'There was,' says *Dr. Sabrazès,* 'a high degree of anæmia and leucocytosis. The clinical symptoms, ganglionic protuberances,

adherence of the skin, œdema, and increase of collateral circulation, point to a lympho-sarcoma. The blood examination is also in favour of this diagnosis, and the proportion of leucocytes excludes the existence of a true leukæmia. The prognosis of such a case of generalized lympho-sarcoma is a fatal termination within a brief period.'

The exposures were made with rays of penetration No. 7, and 4 H. to 6 H. was absorbed at each séance. Séances were given every day, but as seven different areas were under treatment, each area received but four exposures per month. Three weeks after the commencement of treatment a new examination of the blood by *Dr. Sabrazès* gave the following results:

Hæmoglobin	60	per cent.
Red corpuscles	4,947,000	per cub. mm.
White corpuscles	18,600	,,
Blood platelets	698,828	,,
Polynuclear leucocytes ...	69·3	per cent.
Lymphocytes	19	,,
Large mononuclear cells ...	4	,,
Eosinophile cells	76	,,
Transitional forms	78	,,
Neutrophile myelocytes ...	20	,,

Inequality of volume and coloration of the red blood corpuscles. Numerous polychromatic cells; few basophilic granular blood cells; no iodophile leucocytes; a few large lymphocytes; a few points of irritation. Accelerated coagulation, with early retraction of the clot.

'In comparison with the former analysis,' says *Sabrazès*, 'there is augmentation of the red corpuscles, diminution of the white corpuscles, and a less abnormal proportion of leucocytes.'

The amelioration in the patient's condition continued: the dyspnœa almost disappeared, the ganglia were diminished in size, and the general health was much improved.

The treatment was continued, the patient undergoing in all thirty-five irradiations, or five on each region affected. The results were great diminution of the ganglionic masses, decrease in the size of the spleen, clearing of the right lung and of a portion of the left lung, increase of the weight and strength of the patient. This was accompanied by an increase in the amount of hæmo-

globin, and a diminution by one-half of the white corpuscles in the blood.

Although the diagnosis of lympho-sarcoma may be disputed, the result is of the highest importance, even if the case is regarded as one of lymphadenoma or leukæmia. That the X-rays had an undoubted effect on the ganglionic masses and on the composition of the blood and the general health of the patient cannot be disputed.

At the Broca Hospital we had occasion to treat a woman with an enormous tumour of the cervical region, which had been diagnosed as lympho-sarcoma by *Dr. Brocq.* The tumour was hard and adherent to the deeper structures. At the commencement the irradiations certainly produced some diminution of the volume of the tumour, but there was no improvement in general health. After a time obstruction to the breathing occurred, and the patient was transferred to the surgical wards. The result was not very encouraging, but the case did not conform to the ordinary type of leukæmia.

If the lesion is localized, as is generally the case, lympho-sarcoma may be treated in the same manner as sarcoma. The patient should be carefully watched, and the treatment suspended on the occurrence of any signs of toxæmia. When the lympho-sarcoma is more generalized, as in *Professor Bergonié's* case, we may use the method described for the treatment of leukæmia proper.

All we can say at present is that the X-rays give favourable results in cases of lympho-sarcoma, but that further observations are required in consequence of the uncertainty of the diagnosis.

General Lymphadenosis—Hodgkin's Disease.

In the second edition of his work *Williams* reports a patient suffering from Hodgkin's disease, who was greatly relieved by X-ray treatment. The case was that of a man, twenty-one years of age, who had suffered from the disease for a year or more. The treatment lasted seven months, during which time three exposures, each of ten minutes' duration, were given per week. Each diseased area was treated separately. The glands decreased in volume, the health improved, and the general condition of the patient became fairly satisfactory. After cessation of the treat-

ment, however, there was a recurrence of the disease, and the patient died after an interval of nine months. Two other cases were treated in the same manner, with rapid amelioration, but the patients were lost sight of.

Williams considers that at the commencement of the X-ray treatment the results are most astonishing, but he is not able to say anything as to the permanence of the cure. In his first case he is convinced that the general health was greatly improved, and that the life of the patient was prolonged.

The author also cites two cases reported by *Pusey*, in which the beneficial influence of the X-rays was very evident.

The first patient was seen by *Ochsner*, who had diagnosed the nature of the case, and had operated on one side of the lesion, which was in the cervical region. The other side was treated by the X-rays. After two months' treatment the tumour, originally of the size of the fist, had diminished to the size of an almond.

The patient still returns for treatment from time to time, and the disease has shown no signs of increase during the last five months.

The second case had an enormous glandular enlargement in the axilla, of the size of a child's head. Injections of arsenic had yielded no improvement. Radiotherapy was tried by *Pusey*, with a notable improvement of the health and diminution of the tumour, so that the patient was able to play billiards. Ultimately, the axillary glands disappeared entirely. There had been no recurrence after the lapse of some considerable time.

In a case treated at the Broca Hospital, which was probably one of Hodgkin's disease, the use of X-rays was not followed by any very brilliant result. The patient was very cachectic, and did not remain long under treatment.

Moreover, as there was no opportunity to make an examination of the blood, it is doubtful whether this was a case of lymphadenoma or of leukæmia. The same may be said of the cases reported by *Williams* and *Pusey*.

The term 'lymphadenoma' should include only those affections in which there is hypertrophy of the hæmatopoietic organs, without sensible alteration of the blood.

As a consequence of irradiation, we may often see the glandular tumours diminish, the fever decrease, and the health improve; but this observation is not very conclusive, since all these symptoms

may be grouped under the general term 'adenia,' which according to some authorities occasionally disappears spontaneously.

It is true that the spontaneous regression is very rare, and *Heinecke's* experiments show that X-rays have a definite action on lymphoid organs. It is therefore rational to treat lymphadenoma by radiotherapy, but it is to be hoped that in future the exact type of disease will be better defined.

We may include in this chapter certain lymphadenomata, probably of a tuberculous origin, on the exact nature of which authorities are not agreed, but which would probably be ameliorated by radiotherapy. We recommend the employment of rays with a penetration corresponding to No. 7 or No. 8 of Benoist's radiochromometer, with a dose of 3 H. or 4 H. to each region affected, to be repeated once a week.

The treatment must be intermitted if any inflammatory reaction appears on the skin.

Leukæmia.

But few cases of leukæmia have as yet been treated by the Roentgen rays; nevertheless, important results have been obtained in this most fatal disease, and we propose to study the question in some detail.

The first communications on the use of radiotherapy in leukæmia came to us from America.

Senn reports two interesting cases. The first is that of a man. forty-three years of age, suffering from leukæmia of a year's duration. The disease began in the neck, and invaded the axilla, the inguinal regions, the mediastinum, and the tracheal and bronchial glands. The spleen was also greatly enlarged. The blood-count showed the presence of well-marked anæmia. After thirty-four irradiations the glandular swelling disappeared. After three months a fresh enlargement of the glands occurred, which, however, yielded to a further series of ten irradiations. For the last eight months the condition has been satisfactory.

The second case is that of a patient, fifty-three years of age, in whom the disease had commenced ten years before. No treatment had produced the slightest impression. An examination of the blood yielded the following results: Hæmoglobin, 73 per cent.; erythrocytes, 3,875,000 per cubic millimetre; leucocytes, 208,000, of which 78 per cent. were small leucocytes, 14 per cent. large

leucocytes, 2 per cent. transitional forms, and 5 per cent. leucocytes with multiform nuclei.

After fifteen irradiations the glands diminished, and a fresh examination of the blood gave hæmoglobin 85 per cent., erythrocytes 4,450,000 per cubic millimetre, leucocytes 76,000. After another series of exposures, the number of leucocytes fell to 46,500.

The general health of the patient gradually improved, his weight increased, and his pallor diminished.

More recently *Bryant* and *Crane* published some observations on a woman, thirty-three years of age, suffering from myelogenous leukæmia. The spleen was enormously enlarged, and the blood contained 176,000 white corpuscles per cubic millimetre. After a treatment of daily irradiations continued for two months, the case was entirely cured. Arsenic was given during the whole of the radiotherapeutic treatment, and in the author's opinion contributed greatly to the satisfactory result.

The notes of this cure are incomplete, for they merely mention without details a considerable diminution in the number of leucocytes.

The case cited by *Brown* is more complete. It was one of advanced leukæmia, in which the spleen extended below the umbilicus. There were 800,000 white blood cells per cubic millimetre, including 40 per cent. of polynuclear cells, 40 per cent. of myelocytes, 8 per cent. of eosinophile cells, and 8 per cent. of mast cells. At the commencement of treatment the séances were repeated twice a week, and later on every day. From July, when the treatment commenced, to February, the amelioration progressed regularly, with a corresponding diminution in the number of myelocytes. These diminished in exact proportion to the general diminution of the total number of white corpuscles.

By February the cure was complete, and as the X-rays alone were used the results are conclusive as to the value of radiotherapy in leukæmia.

At the Biological Reunion at Nancy *Guillon* and *Spillmann* published a case of supposed leukæmia, but this was not confirmed by microscopic examination of the blood.

Bossolo has treated a case of myelogenic leukæmia by the X-rays. After a temporary increase, the number of leucocytes fell rapidly to from 140,000 to 10,000 per cubic millimetre.

Herman Grad and *Ahrens* have also obtained encouraging results.

In August, 1904, *Aubertin* and *Beaujard* published the results of their researches on the modifications produced in the blood by the X-rays in cases of leukæmia.

These observations are most interesting, as they show the changes occurring in the blood day by day after each irradiation. We reproduce them in detail:

'The patient is a man, sixty years of age, suffering from typical myelogenic leukæmia, which commenced about nine months ago.

'The spleen extends across the middle line and occupies the whole of the left side of the abdomen almost down to the pubis. The liver is enlarged, but there are no glandular swellings. There is anæmia of moderate intensity, the number of red blood corpuscles being 2,500,000 to 3,500,000 per cubic millimetre. The white cells, which were 90,000 in February, 1904, gradually increased in number till they attained 124,000 in the beginning of April. The leucocytic formula which we reproduce on another page is the classical formula of myelogenic leukæmia. Massage of the spleen and the administration of arsenic have had some influence on the general health, and have slightly increased the number of red blood cells; but they had absolutely no effect on the number of white cells, which showed a regular increase.

'Radiotherapeutic treatment was commenced on April 20. The spleen was irradiated before and behind for eighteen minutes every day, with rays of penetration No. 6 and a dose of 5 H., the distance of the anticathode being 25 centimetres. The patient thus received the comparatively large dose of 30 H., which set up a severe attack of radiodermatitis. Under this treatment the number of white cells fell in six weeks from 124,000 to 52,000, while the general health was greatly improved.

'It is interesting to note the manner in which this diminution in the number of leucocytes occurred.

'Some days before the commencement of radiotherapeutic treatment, the number of leucocytes was 124,000. A week later, just before the second exposure, it had fallen to 102,000. Three-quarters of an hour after the termination of the irradiation, the number of white cells had risen to 131,000, thus showing an immediate increase of 30,000 white cells. A week later the number had again decreased to 108,000. After the fourth séance we

examined the blood every two hours, and got the following numbers: Before the exposure, 79,200 ; at mid-day, a quarter of an hour after the termination of the irradiation, 74,000 ; at 2 p.m., 90,000 ; at 4 p.m., 91,000 ; at 6 p.m., 105,000. The next morning the number had risen to 194,000, or nearly double. Two days afterwards it had fallen to 80,300, and continued to fall for three succeeding days, the numbers being 73,000, 64,000, and 61,000.

'The results of the subsequent séances were not so marked, being less intense and longer delayed. After the sixth séance, for instance, the number of leucocytes only increased from 64,000 to 76,000. If we could have kept the patient in hospital we might have got even more marked results.

'These modifications certainly did not depend merely on differences of concentration or dilution of the blood, since the number of red globules did not vary in correspondence with that of the leucocytes, and occasionally the number of red and white corpuscles varied in an inverse order. The alteration was independent of the leucocytosis of digestion, and was greater than any previously observed in cases of leukæmia.

'Without exception, the number of the leucocytes increased immediately after each irradiation, and then gradually diminished to a lower level than before, falling in one instance as low as 52,800 to the cubic millimetre.

'Let us next turn our attention to the alteration in the leucocytic formula. The augmentation in the number of white cells, which is frequently enormous, is not due so much to myelocytes as to adult polynuclear forms. Before radiotherapeutic treatment the blood contained 112,000 leucocytes, 34 per cent. of which were polynuclear cells, 65 per cent. myelocytes (including Turck's cells), and 6 per cent. lymphocytes and mononuclear cells. On the day after the third séance these proportions had greatly altered. The total number had risen to 192,000, of which 52 per cent. were polynuclear, 47 per cent. were myelocytes, and 3 per cent. lymphocytes. On the following day, when the number of white cells had sunk to its former level—72,000—the formula had also returned to its previous proportions. Hence we may conclude that the leucocytosis which follows an irradiation is constituted by an absolute increase in the number of polynuclear cells in the circulation.

'We next set ourselves to determine by a variety of methods if there was any difference in the structure of the leucocytes before

and after radiotherapeutic treatment. Hitherto we have not found any change either in the protoplasm or the granulations, neither degeneration of the nuclei nor evidence of karyokinesis.

'We may note that the red nucleated corpuscles are not apparently influenced by radiotherapy. Their absolute number remains the same, while their relative number is greatly diminished during the leucocytosis following an irradiation.

'As regards the red corpuscles, we have observed a considerable augmentation of their number, even as much as a million, after each séance. This increase in number is accompanied by certain modifications which are not parallel with those of the white cells. We shall return to this question later on.

'It may be remarked that, in spite of the alteration of the blood and the improvement in the general health, there was no permanent diminution in the volume of the spleen. In the patient's opinion, however, a temporary reduction did occur during the two or three days which followed an irradiation, after which the organ regained its previous size. This observation was spontaneously made by the patient, and although we did not verify it ourselves, we cannot help associating it with the augmentation of the leucocytes during the same period.

'We may assume, then, that in the treatment of myelogenic leukæmia radiotherapy produces an immediate effect on the blood, causing a diminution in the number of leucocytes, which does not, however, progress in a regular manner.'

After each séance there is a considerable and sudden rise in the number of white blood cells, after which the number slowly and gradually diminishes to a level lower than before irradiation. After some time the augmentation following each irradiation becomes imperceptible, but a permanent diminution is still noticeable. The leucocytosis affects the polynuclear cells rather than the myelocytes.

These changes in the blood occur before any visible alteration in the size of the spleen.

M. Beaujard has carried out some similar observations on lymphatic leukæmia. In his cases the diminution in the number of white blood cells progresses more regularly, and the augmentation after irradiation does not occur. In the same way the increase in the number of red blood cells is regularly progressive.

In both varieties of leukæmia the general health improves

rapidly, and the spleen diminishes in size to an appreciable extent. In cases where the glands have been previously enlarged these diminish in size, and even in the cases which are not completely cured the best results usually follow radiotherapeutic treatment.

On the other hand, *Barjon*, *Cade*, and *Nogier* presented to the Medical Society of Lyons a case of myelogenic leukæmia which had been unsuccessfully treated by the X-rays. The patient was a man of twenty-four years of age, in a bad state of health, and presented an enormous hypertrophy of the spleen.

A blood-count on October 12, 1903, gave the following results:

Red globules	2,790,000 per cub. mm.
White globules	147,000 ,,

The leucocytic formula was:

Polynuclear cells	24 per cent.
Large monomyelocytes	70 ,,
Eosinophiles	2 ,,
Lymphocytes	0 ,,
Intermediate forms	4 ,,

During a period of three months the patient was subjected to twenty-one radiotherapeutic séances, averaging twelve minutes each, the total irradiation being 265 minutes.

The day following on irradiation there was a lowering of the temperature, and a decrease of the pain over the spleen.

There was no observable diminution in the volume of the spleen, or in the number of the white blood-cells.

At the end of the treatment, a blood-count gave

Red globules	3,112,400 per cub. mm.
White globules	309,380 ,,

being an augmentation of the white blood corpuscles to double their former amount.

The patient ultimately died of cachexia.

It would seem, then, that the X-rays produce a considerable amelioration both in myelogenic and in lymphatic leukæmia.

Notwithstanding the negative results published at Lyons, the experiments of *Beaujard* are in no way invalidated.

The general health of the patients improved, the splenic hyper-

trophy was diminished, and the glandular enlargements were in part absorbed.

At the present time we are engaged in *Dr. Béclère's* laboratory in the treatment of several cases of leukæmia. The interest in this matter is increased when we reflect that all other methods of treatment have proved ineffectual.

As regards the method of application, it is of importance to give the irradiations as frequently as possible, since each exposure is followed by a diminution in the number of the white cells. On the other hand, radiodermatitis must be carefully avoided, since, in addition to the local injury, it compels us to suspend the treatment.

The rays should be of moderate penetration, No. 7 or No. 8 on Benoist's scale, and the tube should be placed at a distance of 6 or 8 inches. This distance is indicated, not only to secure thereby a more uniform irradiation over a considerable surface, but also in order that the quantity absorbed by the spleen and glands may be better distributed.

In a case of typical myelogenic leukæmia, where the spleen only is affected, we usually divide the skin over this organ into four segments. Three of these are carefully protected by means of a leaden shield, and the fourth is exposed to an irradiation of 4 H. or 5 H. If no dermatitis appears, the exposures may be repeated once a week.

During the interval it is advisable to irradiate the ends of the long bones, as recommended by some American authors.

All the long bones should be treated in this way, since it has been found that in every case of myelogenic leukæmia the marrow of the long bones is affected and converted into red medulla.

We can well understand how difficult this is in practice, since the bones are deeply seated and their tissue is very opaque to the X-rays. Highly penetrating rays should be employed, and the more accessible bones should be attacked first.

Where the patient has a number of glandular enlargements, a dose of 3 H. or 4 H. may be given to each affected region at intervals of a week.

In these cases we have never met with toxic phenomena, so that we may safely use the method by massive doses, in preference to fractional doses of $\frac{1}{2}$ H. or 1 H.

Mycosis Fungoides.

It may surprise some of my readers to find mycosis fungoides in the group of tumours of the lymphatic system.

Although this affection belongs neither to the sarcomata nor to the lymphadenomata, we have placed it in this chapter because it resembles them histologically (*Vidal, Brocq, Siredey*).

Mycosis fungoides is a formidable disease which is universally fatal. Hitherto no treatment has had any effect. All sorts of internal and external medications have been tried, without producing even temporary ameliorations.

In July, 1903, *Dr. Brocq* sent to us a female patient from Canada suffering from a mycosis fungoides which was eczematous and ulcerating. She was sent with a view to treatment with high-frequency effleuves, in order to alleviate the intense pruritus. At that time we were ignorant of the work of *Scholtz* on this subject. In conjunction with my friend *Dr. Civatte*, we determined to try radiotherapy.

We had already proved that the X-rays have a favourable effect on other cutaneous tumours, and we were thus encouraged to try their action on mycotic tumours. At all events, there was little risk, and even in case of a violent reaction we hoped that there might be a local amelioration of the lesions.

We first irradiated two or three large tumours which appeared on the head and face, giving a few exposures intense enough to set up a sharp reaction without producing ulceration. Each tumour was treated with a dose of 10 H., which was absorbed during two consecutive séances, the rays being of penetration No. 4 or No. 5. The immediate result was the total disappearance of pruritus during the two or three days following the first exposure. At the end of six or seven days the skin over the tumours became slightly erythematous, and gradually took on a brown tint. It was more supple, and the tumours became softer. At the end of a fortnight the tumours were notably diminished in volume, and the infiltration of the skin had almost disappeared. There was no return of pruritus, and the reaction had entirely died away, leaving only a slight pigmentation. After one or two more irradiations, the tumours totally disappeared. This result was obtained without the reaction exceeding a slight erythema.

Encouraged by these results, we next attacked the tumours of

the face and trunk in succession, with the result that all the irradiated lesions entirely disappeared. Hitherto there has been no recurrence.

Rays of moderate penetration, No. 4 or No. 5 on Benoist's scale, were used, with a dose of 8 H. or 9 H. for each tumour. The prescribed dose was given at one or two séances, and this was followed by an interval of two or three weeks. We waited till the reaction had disappeared or was greatly abated—that is to say, until the erythema had faded, and there was no sensation of burning. At the end of this time, if the tumour still remained hard and the skin infiltrated, we gave another irradiation of 7 H. or 8 H., and again waited for three weeks.

On each occasion the dose was somewhat reduced, and this alternation of irradiation and rest was continued until the lesion disappeared.

Evidently the quantity given during each séance will vary with the size and the situation of the tumour, and the same may be said of the number of applications required. Thus, for a large nodule the size of a nut on the forehead, the eyebrow, or the upper lip, four series of irradiations were required, each consisting of two consecutive exposures, during which 8 H. to 10 H. was absorbed. The total dose was therefore 35 H. to 40 H., divided into four series, with intervals of a month.

On the cheeks, where the tumours were smaller, four séances sufficed, each consisting of two series of two exposures, with a total dose of 20 H. to 25 H.

A small tumour on the eyelid was cured by the absorption of a dose of 9 H. or 10 H.

The patient was treated every day, or every other day, but the area irradiated was altered on each occasion, so that an exposure was not repeated on the same spot until the reaction had disappeared, about twenty to thirty days after the last exposure. By this means we were able to treat a great number of diseased foci without setting up dermatitis.

Certain portions of the body where the disease had taken on an erysipelatoid character were greatly benefited by slight irradiations. The tube was placed at a considerable distance from the skin, so as to obtain an equable irradiation of a large surface. In many instances a dose of 5 H. or 7 H. was sufficient.

In conjunction with *Brocq* and *Bisserié*, we exhibited this patient

to the Société de Dermatologie in February, 1904. The following are *Brocq's* observations on this occasion : 'Although we sometimes see spontaneous arrest of the disease in cases of mycosis fungoides, and even regression of the tumours, these improvements have not the regular and progressive character which was so noticeable in this case. In order to remove any trace of scepticism as to the result, we may add that in every instance the improvement was consecutive to the irradiation of one of the tumours.

'Of all the results which we have obtained by X-ray treatment, this is the most remarkable, and, if we may say so, the most important in its promise for the future. It is true that a superficial epithelioma or other epithelial neoplasm may yield to this most marvellous therapeutic agent, but before the introduction of X-rays a superficial epithelioma could be cured by surgical means, whereas up to this time mycosis fungoides was entirely beyond the help of medicine or surgery.

'We are therefore particularly pleased to be able to present to you this case. The woman is not indeed absolutely cured, and we should have liked to continue the treatment some months longer, in order to show her to you quite free from any trace of the disease. She wishes, however, to return to America, and we have therefore been obliged to exhibit the case before the recovery is complete.

'Mycosis fungoides, then, as well as the sarcomatous neoplasms, is amenable to the action of the Roentgen rays.'

Subsequently this patient was induced to remain in Paris, and radiotherapeutic treatment was continued until October. In July most of the lesions were disappearing, and she returned to Canada completely cured. It is, of course, possible that there may be a relapse, but at the time when she left us all the tumours had disappeared, and there had been no recurrence.

The general health was in no way affected by the enormous quantity of X-rays which had been absorbed during the course of treatment. Not only was there no loss of flesh, but the patient increased in weight at one period of the treatment, gaining some 16 pounds during the months of June and July.

The treatment was interrupted for some time in consequence of an abscess in the axilla, which had to be treated surgically, but this was in no way due to the radiotherapeutic treatment.

We wish to draw attention to the degree of reaction set up

during the treatment. It was not necessary, as *Scholtz* asserts, to set up a superficial ulceration. A slight erythema was quite sufficient, and in no instance was this degree of reaction exceeded. It must be remembered that a dose of 8 H. or 9 H. produces a much more violent reaction on the healthy skin than it does on the mycotic tumour. On the eczematous or erysipelatoid patches, however, this dose was capable of producing a sharp reaction, and occasionally a slight burn. In irradiating these lesions then, it is wise not to exceed a dose of 5 H. to 7 H. at each séance.

There is no object in producing a stronger reaction. On one occasion we accidentally exceeded this dose while treating a group of confluent tumours on the forehead. Desquamation followed, preceded by the appearance of phlyctenulæ, and the patient complained of a burning sensation. The reaction did not proceed further, and the lesion was completely healed in the course of a couple of months. At the present time a smooth white cicatrix covers the seat of ulceration. Although the tumours disappeared, the cure was not so complete as in neighbouring parts where the reaction was more moderate. A slight additional irradiation was followed by the disappearance of the remains of the original tumours.

Another case under our care has been greatly benefited by the X-rays. The patient suffered from mycosis in the eczematous stage, with patches of a lichenoid and erysipelatoid appearance. The pruritus, which was intolerable, speedily abated, and the infiltration of the skin was diminished.

After two or three séances, the skin regained its normal coloration. The quantity absorbed in no case exceeded 7 H. or 8 H. at each séance, and in many places the dose was much less than this. In consequence of the great susceptibility of the skin affected with mycosis, we consider that the dose should never exceed 6 H. or 7 H. for each separate lesion. There should always be an interval of a fortnight or three weeks between successive irradiations.

We may here allude to our previous observations as to the special sensibility of the integument of the thenar and hypothenar eminences, and of the sole of the foot. These regions were affected in both of our cases. We gave a dose of 10 H., relying on the general opinion that the palm of the hand is less sensitive

to the action of the rays in consequence of the thickness of its integument.

This quantity, which usually produces only a pronounced erythema, here set up a sharp reaction accompanied by severe pain. In one case the mycotic lesion rapidly began to heal, and reaction only set in a fortnight after the last irradiation. The epidermis was shed, and the cicatrization was very slow. These phenomena seem to point to a special sensibility of these regions. No other explanation appears possible, since similar results were obtained in two different cases.

In mycosis fungoides radiotherapy appears to give most excellent results not otherwise obtainable. The treatment demands a considerable expenditure of time and money, but it is painless, and it at once relieves the patients from pruritus, from which they often suffer severely.

We may indeed be certain of curing the terrible itching which usually accompanies the evolution of mycosis. Both in pruriginous tumours and in premycotic patches the itching rapidly decreases during the first few days after irradiation. In many instances even it is relieved on the same evening. The relief of pruritus alone would make the X-rays a welcome adjunct in the treatment of this disease.

More than this, it certainly causes at least a temporary disappearance of the local lesions. It is impossible to speak with certainty as to the recurrence, since our cases have not been sufficiently long under observation. In a certain number of cases, however, the disease has remained cured for a year or more without any sign of recurrence.

As yet we have not had an opportunity of trying this treatment on the ulcerative forms of the disorder, but we see no reason to doubt that it would be equally efficacious in this variety.

The future alone can decide if the cachexia disappears along with the local lesions, and whether the patient may be said to be completely cured of the infective neoplasms. At all events, we have every reason to hope for a favourable result, since the general health of the patient has been greatly improved in every case that we have treated.

We are entirely ignorant of the mechanism by which the X-rays produce a favourable effect on this disease. Probably they have a

PLATE VII.

MYCOSIS FUNGOIDES (CASE 1).

Before treatment.

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PLATE VIII.

MYCOSIS FUNGOIDES (CASE 1).

Photograph taken after absorption of 500 H. at different points.

To back p. 353.

selective action on the cells of the new formation, but this is purely hypothetical.

In July, 1902, *Norman Walker* and *H. A. G. Brooke* reported favourable results in a case of mycosis treated by radiotherapy.

Scholtz, in a work published in 1902, expresses himself thus: 'In two cases of mycosis fungoides some small tumours have disappeared after irradiations of sufficient intensity to produce necrosis of the skin. The patients were not, however, much benefited by the treatment, as new foci of disease appeared elsewhere.' In a further note he relates a third case, in which the tumours were influenced in a striking manner. The histological microscopical examination has been made of a mycotic tumour which had been treated by X-rays, but this did not furnish any information of importance.

Hyde has published a case of cure. His patient presented numerous ulcerated tumours of the scalp, accompanied by lesions on the trunk in different stages of evolution. The case was greatly improved, and the ulcerations healed. The same author obtained an apparent cure in the case of a female patient suffering from this malady.

In August, 1903, *Marsh* published a successful case.

Jamieson also speaks highly of the value of the treatment, which he considers capable of arresting the evolution of the disease.

A. E. Carrier, in the *Journal of Cutaneous Diseases* for February, 1904, has also published some interesting observations on a similar case. Like ourselves, he tried the treatment empirically, giving short exposures daily, and avoiding all severe reaction. The treatment was commenced in August, 1903, and the case was completely cured by November of that year. He reports the relief of pruritus and the progressive diminution of the tumours; but, as is proved by the photographs, the disease was not so severe as in our case, which may account for the shorter duration of the treatment. Without denying the efficacy of other methods of treatment, which, however, had failed in this case, he considers that the X-rays are capable of completely arresting the evolution of the disease.

More recently *Scholtz* and *Riehl* have obtained good results in a case of premycotic infiltration of the skin.

In the evolution of this disease *Morelle* distinguishes two periods—the premycotic period, before the appearance of tumours, and the period of confirmed mycosis, with the occurrence of tumours. Some observations of his appear to show a beneficial action of the X-rays on the lesions which characterize the second period.

In our opinion radiotherapy is equally beneficial in all stages of premycotic lesions — eczematous, erysipeloid, or infiltrated. In these cases the irradiations should be of shorter duration.

Dubois-Havenith presented to the Medico-Chirurgical Society of Brabant a woman who had been cured of an extensive mycosis fungoides by means of the X-rays. Although all the tumours had disappeared, it was impossible to say if the case was permanently cured.

In conclusion, the following are the rules for treatment in a case of mycosis: An irradiation of 7 H. to 9 H. should be given to each tumour at each sitting. In cases of mycosis in the eczematous stage, the quantity should not exceed 7 H. A period of twelve to twenty days should elapse between two irradiations.

Case I.—M. G. B., aged thirty-nine. Mycosis fungoides. Received into the Vidal Ward on May 20, 1903.

No history of heredity. At the age of sixteen she had a patch of eruption as large as a shilling behind the right ear, which was covered with crusts, and itched violently. This persisted for two months. She went to Montreal, was married at the age of twenty-six, and had several children.

At the age of twenty-six an eruption the size of a sixpence appeared on the left cheek. This pruriginous patch was covered by a furfuraceous desquamation, which occasionally became raised and congested in consequence of the itching and scratching.

The patient was enceinte, and during the course of gestation there was an outbreak of fresh eruptions on the forehead and cheeks. The lesions are scanty, but the patient complains of violent itching of the face and scalp, particularly at night. After delivery the severity of the itching greatly diminished.

At each pregnancy the pruritus regains its former violence, to be again diminished after delivery. During this period new lesions appear, which follow the same course of evolution. At first congestive maculæ, which become squamous, make their appearance. These rapidly become raised, and persist as permanent elevations. They are red in colour, with a furfuraceous desquamation of the surface. The patient had been under treatment, and had tried ointments and scarifications and an indiarubber mask without result. The lesions were then confined entirely to the face.

Soon, however, they began to spread; a spot occurred on the right thigh, and this was followed by others on different parts of the body.

Scarifications, tincture of iodine, and other irritating applications were tried in vain.

Three years ago two lesions on the chin began to show signs of superficial ulceration. These were removed by a surgical operation, and this was repeated on three successive occasions, with the addition of cauterization. The elevated lesions on the chin did not recur, and cicatrices, which are visible in the photograph, still mark their former position.

New eruptions, however, continued to appear on the trunk and on the scalp.

The general health remains good. The patient, who had lost flesh after the cauterization, soon regained her former weight.

She came to Paris for treatment, and entered the hospital on May 22, 1903.

Examination on Entry.—The eruption covers the face, the neck, the shoulders, the arms, and the forearms. It is more marked on the surfaces of flexion, is absent over the front of the thorax, and is scanty over the abdomen and flanks. It is abundant on the loins, the hips, the lower part of the belly, and the front and inner surfaces of the thighs. It attacks the popliteal spaces, but is absent from the axillæ, the inguinal regions, and the bend of the arm.

The hands are unaffected, but there are a few lesions on the soles of the feet.

The eruption presents a peculiar mottled appearance. The individual lesions vary in size and arrangement. Here and there are white cicatrices due to previous caustic applications. On the arms the coloration is more intense than on the legs.

The eruption on the face and that on the body are entirely different in appearance.

Elementary Lesions.—In some places the lichenification is diffuse, whilst in others it is sharply circumscribed. Under the lichenification there is more or less infiltration, which causes an elevation. To these two factors, lichenification and infiltration, there is often added a third—viz., a pigmented erythema.

The eruption varies in different regions of the body.

Face.—Here there is a predominance of infiltration. The cheeks are covered with rose-coloured patches, of regular contour and well-defined margin, raised 3 or 4 millimetres above the level of the skin. There is slight desquamation of the surface. When this is removed by means of an ointment, the lesion appears of a rose-red colour with a somewhat livid tint. The grain of the skin is unaltered, dotted over with pilosebaceous orifices, which become more dilated as we get nearer to the middle of the face. In this situation the lichenification is at a minimum. The skin is not wrinkled, but stretched by the subcutaneous infiltration. Here and there the individuul lesions run into one another, forming patches of infiltration bounded by a sinuous line. The forehead especially is covered by raised patches.

The eruption is hard to the touch, and non-adherent to the deeper tissues. It is apparently situated in the upper layers of the corium.

NECK.—The eruption is less raised and not so sharply outlined. The raised portion shades off gradually into healthy tissue, which has nothing abnormal about it with the exception of slight congestion and infiltration.

TRUNK AND LIMBS.—The lesions on the trunk and limbs have a similar appearance. Some are bright red, others are yellowish brown in colour. There is more or less lichenification, but the edges are well marked. This is equally the case when the lesion is raised, lichenified and infiltrated, and when it consists merely of a brown stain with slight lichenification and no infiltration.

On the face especially some of the affected spots present grains of milium, or small miliary abscesses.

The dorsum of the hand is free from eruption. There is a typical lesion on the fourth finger of the right hand, with a good deal of infiltration and hyperkeratosis.

There are two diseased spots on the sole of the foot. These are smooth and red, with raised margins.

The patient says that these desquamating areas were produced by the shedding of the hardened epidermis, which had been raised by a blister. A similar phenomenon had occurred in the left palm.

The eruption on the forehead has encroached on the border of the hair, where it has produced an alopecia. Small red nodules, from which the hair can be easily pulled out and which itch violently, are present over the whole scalp. Here and there are lesions in process of regression. These are rounded patches, a centimetre in diameter, quite bald, reddened in colour, but with no trace of infiltration. The lesions in the scalp are very variable, whereas in other regions they appear fixed. At the present time the disease seems to be progressing only in the scalp.

SUBJECTIVE SYMPTOMS.—The patient suffers from horrible itching. This symptom precedes the eruption, and occurs before there is any other evidence of the disease. The first sign of disease is a slight redness of the skin; this subsequently becomes infiltrated, and the lesion makes its appearance. The itching increases, and is accompanied by a sensation of pricking and burning, especially at night-time on getting warm in bed. This is followed by a short period of comparative calm. After a few days the pains recur, and this alteration continues until the lesions disappear under the influence of radio-therapeutic treatment.

HISTOLOGY.—Microscopical examination was made by *Dr. Civatte.* In the papillary body are found a number of nodules of infiltration, in the centre of which are dilated blood capillaries containing polynuclear cells. There is also some infiltration of the dermis, which seems to encapsule certain small bud-like collections of cells which are found between the papillæ. The infiltration does not extend into the germinal layer, and the epithelium is not penetrated by the leucocytes.

These appearances, which are not in themselves very characteristic, may be interpreted as indications of early mycotic lesions. The clinical aspect of the eruption did not admit of any possible doubt on the matter.

TREATMENT.—From May to July, 1903, the patient had undergone treatment without any benefit. This consisted of external applications, high-frequency electricity, and injection with Fowler's solution.

In July, 1903, phototherapy and radiotherapy were tried, and since the latter treatment was followed by great improvement, it was determined to continue it.

At the commencement of treatment the condition of the patient was still further aggravated ; the tumours had increased in size and were more infiltrated. The photograph on Plate VI. gives a good idea of the appearance of the face.

July 24, 1903.—An irradiation was given to a large tumour in the left temporal region. The dose absorbed during two consecutive séances was 10 H. The tumour disappeared after some time, the pruritus abated, and up to the present there has been no recurrence.

From July 24, 1903, to February 4, 1904, the patient received 100 applications—that is, fifty series, each consisting of two applications, with a mean dose of 8 H. to 10 H. for each series, thus giving a total dose of over 500 H.

The quantity of the X-rays absorbed by each tumour before disappearance varied greatly according to its volume. Thus, the large tumours on the forehead required four series of exposures, with a dose of 10 H. for each series, giving a total exposure of 40 H. The interval between the administration of each dose of 10 H. was about three weeks.

On the cheeks, where the lesions were smaller, two series sufficed, each series consisting of two exposures.

On the eyelid, which was the seat of a small lesion, a single irradiation of 9 H. or 10 H. was sufficient.

From February 4 to June 1 the patient received seventy-six applications, with doses varying from 9 H. to 10 H. This makes a total quantity of nearly 1,000 H. absorbed by the various lesions. Usually 5 H. to 8 H. was sufficient to cause the disappearance of a simple lesion consisting only of redness and infiltration. On the nodular patches 10 H. to 15 H. was required, according to their size. The first series consisted of one or two exposures of 9 H. or 10 H. This was followed after a month's interval by another of about 8 H., after which much smaller doses were given, until the lesion had entirely disappeared.

No serious reaction occurred except on the thenar eminence, where a slight radiodermatitis was set up, which, however, soon disappeared.

The following was the usual course of evolution : On the evening after an irradiation the itching was usually aggravated. The pruritus diminished after two or three days, and ceased entirely as soon as the lesions began to decrease in size. From two to eight days after irradiation an erythema, accompanied by pigmentation, made its appearance. The period of latency varied according to the sensitiveness of the region, the gravity of the lesion, and the dose of the rays. The reaction seemed to be more violent on the lichenoid and infiltrated patches than on the nodular tumours.

A few squamæ then appear on the irradiated surface, with a slight amount of oozing. This soon ceases, the skin becoming dry and beginning to desquamate.

At this period the pigmentation is very pronounced, and the infiltration is considerably diminished. Two months later there is no trace of reaction, and the lesion has disappeared.

The larger tumours begin to diminish in volume fifteen days after irradiation with a dose of 9 H. or 10 H.

Then gradually, without any marked reaction, the tumour begins to waste away, and the skin assumes a brown or blackish appearance. Desquamation follows, the integument becoming whitish in colour, and covered with furfuraceous scales, which are easily detached. Finally the whole assumes its normal appearance.

In no instance has there been any recurrence of a lesion that has been entirely cured, nor has the pruritus returned. Lesions which have been imperfectly cured have increased after a time, but a second series of exposures has resulted in their complete disappearance.

On account of the number of the lesions, the patient is not yet entirely cured. She is still receiving one or two exposures every morning with a dose of 5 H. or 7 H. Her general health is excellent, and she has increased 16 pounds in weight during the last two months.

The patient returned to Canada in October, completely cured of all her objective symptoms.

Case II.—M. D., aged fifty. Premycotic erythema. No special history.

The disease began six years ago by two patches the size of a halfpenny, of a yellowish colour, on the internal surface of the thighs. They were not raised, and did not give rise to any itching.

After six months they became pruriginous ; the patient began to scratch, and redness and infiltration followed. She was treated by various external applications without result.

A year afterwards a fresh eruption appeared on the thighs and back. These were preceded by violent itching and an appearance of redness. The disease gradually extended, and similar lesions appeared on the whole of the body and face. At present the appearance is greatly modified ; the infiltration has increased, the erythema has persisted, but it is interspersed here and there with irregular yellow patches. The itching is terrible, and after treatment by various methods without success, she was admitted into the hospital. She presents at the present time a number of large circinate patches, some red and others yellow in colour. They are infiltrated, and raised 1 or 2 millimetres above the level of the skin. Their borders are irregular, and in consequence of scratching the surface is moist and very sensitive.

Histological Examination.—*Dr. Sabouraud* made a bioscopic examination, but found nothing characteristic. A second examination was made at the Broca Hospital, and a certain amount of perivascular infiltration was made out.

Treatment.—From January 21 to June 10 she has received ninety applications of X-rays.

The dose has varied from 5 H. to 10 H. Some of the lesions which were more infiltrated needed a second application three weeks after the first.

Usually the itching ceases at once after irradiation. Occasionally, however, it is increased for the first two or three days, to disappear entirely later on.

As a result of irradiation, the redness of the skin is at first augmented. It then becomes brown and desquamates, and the infiltration entirely disappears. The whole course of evolution lasts one or two months.

Although the total dose absorbed was over 500 H., the general health remained unaffected.

There has been no recurrence.

The patient is still under treatment, but the face, the neck, and a great part of the body is completely healed. After a moderate irradiation a slight radiodermatitis occurred on the thenar eminence, but this soon passed away.

CHAPTER IX

RESOLVENT ACTION ON EPITHELIAL NEOPLASMS

Verrucæ—Cutaneous Horns.

In three instances patients suffering from verrucæ have been satisfactorily treated by *Sjögren* and *Sederholm.*

Scholtz also treated a case of warts of the scalp by a moderate irradiation. The warts disappeared without the production of alopecia. A cutaneous horn was cured in the same manner. On the other hand, in a case of warts on the hand an intense irradiation produced no effect.

Varney obtained good results by this method.

Dr. Kothe of Bonn has treated some cases of verrucæ by a new method of procedure. His results were obtained accidentally in the course of some experiments on the action of the Roentgen rays after the injection of eosine. A 1 per cent. solution was used, and the warts disappeared after a short exposure. A similar exposure had no effect on the parts which had not been injected. To be conclusive, this experiment should have been carried further, and a number of warts should have been injected without irradiation, to see if the eosine alone was not the cause of their destruction.

Holzknecht advises a dose of 8 H. in a single séance, with careful protection of the surrounding skin.

We have treated a number of cases with the X-rays, almost invariably with excellent results.

In one case several flat verrucæ of the face yielded to a single irradiation of 4 H. The patient had a number of similar lesions on the arms. The warts on the face had entirely disappeared one month after the single irradiation, while those on the arms were unaffected.

A cutaneous horn on the nose was also removed by the X-rays. A plate of lead was prepared, with an aperture corresponding

exactly to the dimensions of the horn. Rays of penetration No. 6 were used, and the horn was exposed to an irradiation of 10 H., while the face was protected by the lead mask.

A fortnight afterwards the horn had changed in appearance. It was shrunken and atrophied; it had altered in colour, and the base was of a violet tint.

A second irradiation was given under similar circumstances, with a quantity of only 3 H. A fortnight later the horn fell off, leaving a scar which was hardly visible.

The most interesting case that we have met with is that of a young girl seven years of age, with enormous warts, about a dozen in number, on the fingers and metacarpal region. There was also one isolated wart situated on the external surface of the thumb. In order to protect the skin, which was very sensitive, we improvised a protective shield of mercurial plaster. A cast of the lesion was taken, and by aid of this apertures were cut corresponding to the verrucæ. The nails were protected by small plates of lead. A certain number of the less penetrating, and therefore more injurious, rays were arrested by the mercurial plaster, and we were thus enabled to give an irradiation of 8 H. with safety.

There was no marked reaction, and a fortnight later, on January 28, the warts were softer in consistence. A second irradiation was given of 6 H. or 7 H.

On February 13 the warts were flattened, and there was some reaction in the neighbourhood of the joints. We waited for another fortnight, and then gave an exposure of 4 H.

On April 7 all the warts had completely disappeared, with the exception of the one situated on the thumb, which in consequence of its position had not been exposed to the action of the rays.

This is an interesting case, since there can be no question here of spontaneous regression; for why should regression take place only in the case of those lesions which were attacked by the rays? It is much more logical to suppose that the radiations themselves determined the disappearance of the lesions.

We are far from denying the spontaneous disappearance of verrucæ in certain instances, in consequence of which so many fanciful remedies have acquired a reputation for the cure of warts.

We would only insist on the fact that the X-rays have a destructive action on certain forms of this lesion.

In the treatment of a true cutaneous horn we may give a dose of 10 H. at a single séance, with rays of penetration No. 6 or No. 7, taking care adequately to protect the neighbouring skin.

For ordinary verrucæ a dose of 7 H. or 8 H. should not be exceeded.

A single application is often enough, although occasionally a second irradiation may be necessary a fortnight later.

Case I.—L. T., aged nineteen. Verrucæ on the dorsal surface of both hands, of eighteen months' duration, increasing in size and number.

November 11, 1903.—An exposure is given, the hands being held side by side, and the focus-tube placed at some distance, so as to irradiate the whole surface of both hands. Soft rays of No. 5 quality are used, with a quantity of 4 H. or 5 H.

The patient is probably cured, as he did not return, although he promised to do so if the warts did not disappear.

Case II.—M. O., twenty-three years old. Has a cutaneous horn on the nose, which is 8 millimetres in length and 5 millimetres in thickness. It has been in existence for more than a month, and the fear of the resulting scar has prevented her from having it removed by a surgical operation.

A plate of lead is prepared to shield the healthy skin while irradiating the lesion.

December 1, 1903.—Dose of 10 H. with rays of quality No. 6.

December 15.—There is a violet-coloured zone all round the horny wart corresponding to the irradiated area. The horn is soft and diminished in length, and is beginning to desquamate. A second dose of 3 H. was given, and a fortnight later the horn fell off, leaving a scar which was barely visible.

Case III.—Mme. D., aged thirty-two. For the last two years has had a number of flat warts on the face. Similar growths are to be seen on the arms.

The eyes, the lips, and the hair were protected by plates of lead, and the face was irradiated with a dose of 3 H. or 4 H. on each side, using rays of slight penetration (No. 5).

One month afterwards the patient returned completely cured. All the verrucæ had disappeared from the face without the appearance of any reaction. The warts on the arm, which had not been irradiated, still remained.

In this case it will be noted that only those lesions disappeared which had been exposed to the action of the X-rays.

Case IV.—Mlle. H. H., aged seven and a half. A considerable number of large warts were situated on the dorsum of the left hand. A large wart on the thumb could not be irradiated in consequence of its position.

January 16.—A dose of 8 H. with No. 5 rays. The healthy skin is covered with mercurial plaster.

January 28.—The warts are softer and slightly smaller. Dose of 6 H. or 7 H.

February 13.—The warts are diminished in volume, and some of them have disappeared. They are detached in fragments. No disagreeable sensation is felt. There is a slight redness around the lesions. The treatment is interrupted.

February 27.—The reaction has abated, and the amelioration continues. A dose of 4 H. is given.

March 17.—The amelioration is considerable. The reaction is still apparent.

April 7.—All the warts which have been irradiated have entirely disappeared. The skin has regained its normal appearance, with the exception of a certain degree of pigmentation in places. The wart on the thumb which had not been exposed to the rays is absolutely unaltered. A dose of 5 H. is given to this.

This is an interesting observation, since all the lesions were cured except the one which had not been exposed to the rays. There could be no question here of spontaneous recovery.

Cancer.

Long before *Roentgen's* discovery various forms of electrical energy were employed in the treatment of malignant tumours.

In a few rare instances we heard of complete recovery, but it may be questioned if the diagnosis in these cases was very exact. Most of the treatment was only palliative, and we may say that all varieties of electrical treatment have been tried without result.

The whole aspect of the case is changed since *Roentgen's* discovery and the employment of the new form of energy as a therapeutic agent.

The first experiments were made with caution, but when the technique was better understood, a number of morbid processes yielded to the action of the Roentgen rays.

Among others, cancer was the object of a number of experiments and after a period of indifference, the medical world woke up to the importance of radiotherapy in this disease. Conscientious observers determined to test the value of the new treatment for themselves. In some cases it proved satisfactory, in others it was unsuccessful. Nevertheless the idea spread that cancer could be modified, ameliorated, and even cured by the new process.

Following on the dermatologists, the surgeons took up the subject, when they found that favourable results were obtained not only in epithelioma of the skin, but also in neoplasms of the deeper tissues. To-day the radiotherapeutic treatment of cancer has

become fashionable. Articles appear in the medical journals, and discussions on the subject occupy the attention of all the medical societies. It is applied not only to neoplasms of the skin, but to tumours of deeper organs—the stomach, the liver, the kidneys, and the intestines, and to cancerous neoplasms of the breast, the tongue, and the uterus.

Radiotherapy does not act as a caustic, but as a resolvent. It determines the retrocession of the cancerous process, and in this respect differs from all methods of treatment hitherto employed, with the sole exception of serotherapy, which as yet has had no very great success.

In our opinion, radiotherapy is not as yet capable of modifying all forms of cancer. We say modify, for we cannot use the word cure, since, notwithstanding a number of undoubted and most encouraging results, our experience is still too short to enable us to speak with certainty on this point.

Success is almost certain in cutaneous neoplasms; it is rare in cancer of the breast and internal organs. Forms of the disease which are exactly similar in appearance differ in their reaction to the X-rays. Some are ameliorated, while others remain stationary or progress to a fatal issue. The cause of this difference may consist in a difference in the nature of the disease itself or of its surroundings.

We are thus driven to study in detail the different localizations of cancer and its various forms. We shall indicate the method of treatment and the results obtained in each variety, commencing with a short historical sketch of the subject and concluding with its histology and pathology.

Historical Sketch.—It was a Frenchman, *Dr. Despeignes* of Lyons, who first attempted to treat cancer by the X-rays. In 1896 he published notes of a case of malignant disease of the stomach with advanced cachexia. A week's radiotherapeutic treatment was followed by diminution of pain and reduction in the size of the tumour. In spite of this, the case proceeded to a fatal termination. The patient was treated at the same time with serum injections, a milk diet, and internal medicine; it was therefore difficult to determine what part radiotherapy had in the temporary improvement.

Encouraged by the success of *Schiff* and *Freund* in the treatment of lupus, *Thor. Stenbeck* used the X-rays in the treatment of cancer

of the skin. Success attended the experiment and a radical cure was obtained, leaving a hardly visible scar.

Sjögren and *Bollaan* confirmed these results.

Reports of their success reached the New World, and American physicians, attracted by the novelty of the process, undertook a series of experiments of the subject. They at once enlarged the sphere of action of the X-rays. In his first publication on the subject, *Merill* alludes to a recurrent cancer of the breast, which was treated by radiotherapy, and *Williams*, *Johnson*, and others obtained satisfactory results in similar cases.

Following the example of *Merill*, *Clark*, in June, 1901, published a case of ulcerated cancer of the breast, which had cicatrized almost completely.

From this time frequent reports of cases treated by X-rays came from America. At the Congress of the American Roentgen Ray Society in 1901, *Pfahler* of Philadelphia read a paper on the cure of cutaneous epithelioma, and in the same year two other memoirs appeared by *Chamberlain* and *Towle* on the same subject.

In 1902 treatment by X-rays became more frequent, and reports of neoplasms cured by this means were published by *Cleaves*, *Struver*, and *Sailand*.

In June, 1902, *Coley* reviewed the whole subject before the American Association of Surgery. He came to the conclusion that the X-rays have an indubitable action on neoplastic growth, that deep-seated cancer is also influenced, and that in all cases they produce a diminution of the pain. Later on, *Snow*, *Skinner*, *Gibson*, *Sweet*, *Morton*, and others, published reports of cases treated, and endeavoured to explain the pathology.

In 1903 American physicians adopted the new treatment with even greater enthusiasm, and innumerable works on the subject appeared. One of the most interesting of these is that of *Skinner* in the *Medical Standard* for March, 1903, which contained a most able résumé of the whole subject.

Whilst this progress was being made in America, Europe seemed to be at a standstill. The first reports were received with incredulity, and, either from scepticism or ignorance of the technique, no European practitioner was found to take up the new treatment. Radiotherapy was exclusively reserved for the treatment of cutaneous diseases. In the literature of the subject we can only discover the works of *Lejeune*, of *Schüller* and *Perthes*, and

the manuscript report of *Doumer* and *Lemoine*, which was sent to the Academy of Medicine in May, 1903.

An interesting review by *Albert-Weil* and *Gaullieur l'Hardy*, from which we have already quoted, first made known the labours of American observers to French readers.

The interest aroused in Europe soon bore fruit: results were published by *Mikulicz*, *Schiff*, *Perthes*, *Kienböck*, *Freund*, *Holzknecht*, *Scholtz*, *Ehrmann* and others.

In France we may draw attention to the work of *Vigouroux*, *De Mondain*, *Belot*, with *Brocq* and *Bisserié*, followed by *Béclère*, *Haret*, *Oudin*, *Tuffier*, *Doumer*, *Lemoine*, and many others.

In the beginning of 1904 radiotherapy took a more assured position in the treatment of cancer. Although its efficacy is doubted by many and denied by some, it has nevertheless made great progress. It has, at all events, obliged those who affected ignorance and indifference to attack it openly, which is in itself a step in advance.

After this date the works on the subject are so numerous and the successes so frequent, that it is impossible for us to pass them all in review, however briefly. Here we must bring the history of the movement to an end, reserving a notice of the more interesting publications to the chapters on each separate disease.

We have shown the evolution of the X-ray treatment of cancer, which was initiated in France, tried in Europe, and greatly developed in America, coming back to us from the New World almost like a new discovery, unknown to us before.

Cutaneous Epithelioma.

In 1900 *Thor. Stenbeck* published two cases of cancer treated by the X-rays. One of the patients had crateriform ulceration of the nose. After careful microscopic examination the case was diagnosed by *Sederholm* as an epithelioma. Treatment was continued from July 4 to April 31 of the following year, and resulted in complete recovery. The second case of rodent ulcer was likewise completely cured, the treatment lasting from September 15 to December 15, 1899. The lesions were completely healed, and the scar-tissue was supple, and almost like normal skin.

About the same time *Sjögren* obtained a marvellous cure of an epithelioma of the face. The crusts fell off and the ulceration

healed, complete cicatrization being obtained in the course of two months. The reaction was moderate, and the appearance of the cicatrix was most satisfactory. The case is reported in *Magnus Möller's* able monograph on the influence of light on the skin.

These successes were confirmed by *Bollaan* in collaboration with *Stenbeck*.

From the year 1900 *Johnson* and *Merill* employed this method in America. They reported that it diminished the suppuration in cases of cutaneous epithelioma, and that the resulting cicatrices were very satisfactory. They used soft tubes, and set up sharp reaction. Some fifty séances were needed to obtain a complete result.

In England *Sequeira* treated a number of patients suffering from cutaneous epithelioma. Of eighty cases, thirty were cured. In his opinion the unfavourable results are met with in those cases where the disease has attacked the bones and cartilages. In a paper read before the Manchester Congress of 1902, he recognised the fact that a certain number of recurrences are met with in cases which had been apparently cured, as far as objective symptoms were concerned. A new series of exposures, however, speedily caused the disappearance of the recurring lesion. He describes the edges of the carcinomatous ulceration as being more obstinate and slow in healing.

Subsequently the publications of *John Lee*, *Skinner*, *Gibson*, *Coley*, *Allen*, and others, confirmed the reports of their predecessors, and gave additional evidence of the value of radiotherapy in this disease. *Williams* writes: 'After having cured several cases of cancer by the new treatment, I gained confidence enough to be able to assure my patients that they would be most certainly cured if the tumour from which they suffered was really cancerous in its nature. When I was in doubt as to the nature of the tumour, I gave a more cautious prognosis. I soon found that other neoplasms were equally amenable to radiotherapeutic treatment. In the X-rays we have a most powerful curative agent for nearly all cutaneous tumours, except those of syphilitic origin.'

Grubbe has come to the same conclusion. 'The X-rays,' he says, 'which are very efficacious in the treatment of malignant tumours, probably act by stimulating phagocytosis.'

Of late years radiotherapy has become, particularly in America, the ordinary method of treatment. *Chamberlain* reports thirteen

cases of cancer, the greater number of which were cured by the X-rays. He used a hard tube with successive exposures of five or six minutes each.

Ferguson, *Startin*, *Rutheford*, *Butler*, *Stuver*, and others, had equally good results.

In 1902 *Taylor* presented to the Medical Association of Liverpool four patients affected with epithelioma of the face, whom he had cured by the use of the X-rays. In three of these cases the cicatrization was complete; in the fourth case the condition was improved, and the pain was completely relieved.

Pugh treated four cases of rodent ulcer with good results. The cures were completed after thirty-six, thirty-five, thirty-two, and twelve séances respectively, each being of five to ten minutes' duration.

Pfahler had four cases, two of cancer of the nose and one of the eyebrow. Three of these were cured and one was improved.

Merill has seen cases which had been cured two years and a half previously, and which showed no signs of recurrence. As a result of his experience he gives the following figures: Recovery, 62·5 per cent.; amelioration, 25 per cent.; unaffected, 12·5 per cent.

Snow, *Sweet*, *Shields*, *Sailand*, *Vance*, and *Butler* have also obtained excellent results.

In a number of cases *Coley* has used the injection of toxins in addition to the X-rays. He is convinced of the superiority of his method over other modes of treatment.

In most of his cases *Turnure* reports successful results in the treatment of superficial epithelioma. In one case, however, that of a cancer of the lower lip, which recurred three weeks after extirpation, the lesion was not apparently influenced by the X-rays. The duration of the séances was therefore increased, the only result of which was that an ulcer of considerable extent appeared on the lip.

In discussing the pathogenesis of the cure of cancer *Pusey* considers that the X-rays are able to destroy tissues of less resistance, without injuring the healthy stroma in which they are imbedded. The more he sees of the treatment of epithelial tumours by radiotherapy, the more is he convinced of its efficacy. The cicatrices are very satisfactory, and the results quite as durable as those obtained by surgical treatment. Some of his successful cases have had no relapse after a period of eighteen months, and from the

appearance of the cicatrices he has every reason to believe that the cure is permanent. The principal advantages of the method are the ease of its application, the absence of pain, the smoothness of the scar, and the adaptability of the method to inoperable lesions, or where an operation would be difficult, as on the eyebrow or nose. He finds that radiotherapy is not so successful in cases affecting the lower lip.

Stelwagen maintains that the disease on which radiotherapy exercises the most beneficial effect is epithelioma. He is quite convinced of its value in cases of rodent ulcer and superficial epithelioma. It is, however, not equally efficacious in all cases; some improve quickly, some very slowly, while others do not seem to be affected. Thus he obtained no result in a case of *Paget's* disease in the eczematous stage, whilst the result was most favourable in a case of ulcerative epithelioma of the eyebrow. Healing may be completed without any sloughing or destruction of the affected tissues, but in other cases an ulceration occurs, which gradually fills up with healthy tissue. The duration of the treatment is very variable.

Stelwagen was one of the first to advise the mixed method, consisting in a superficial operation, followed by a series of irradiations in order to prevent recurrence. He thus explains his method: 'I am more and more convinced that the best treatment for ordinary cases is enucleation, either by excision, curetting, or cauterization, followed by a series of irradiations. This method gives a more rapid result, with less chance of relapse. Many patients however prefer the painless treatment by X-rays to the more energetic and rapid procedure.'

He sets up a moderate reaction. 'At the beginning of the treatment,' he says, 'the tube is placed at a distance of 10 to 12 inches, and the exposure lasts five minutes. This is repeated twice a week for a fortnight. If at the end of this time there is no reaction or amelioration, the irradiations are repeated three times a week, with a duration of ten minutes, at a distance of 8 inches. This distance may be gradually diminished to 5 inches. If there is no improvement, the séances are prolonged to fifteen or twenty minutes, so as to produce a slight erythema. Occasionally a slight dermatitis occurs, necessitating the suspension of the treatment. This sharp reaction is often followed by an amelioration, which continues long after the dermatitis has disappeared.'

J. Morton of New York recommends the use of soft focus-tubes in the treatment of superficial epithelioma. He considers that the judicious use of X-rays will prevent the recurrence of cancer after operation, and that radiotherapy is often preferable to operation, which does not give a very high percentage of permanent cures. The results of radiotherapy will compare favourably with those from surgical treatment.

Rinehart gives the following as the advantages of the new treatment: It is not painful, the cicatrix is good, and it is possible to insure by its means the complete destruction of the morbid lesions.

By taking the cases of *Allen*, *Zeisler* and *Childs* together we get a total of twenty-three cases, with seventeen cures.

In the opinion of *W. Newcomb* it is not necessary to set up violent dermatitis. From an experience of thirty-one cases he draws the following conclusions: If not too far advanced, epitheliomata of small extent are easily healed with little or no scarring. When the disease has invaded the deeper layers, the cure is more difficult, although it follows in a majority of cases. Recurrences are common, but yield readily to treatment. In nearly every instance there is relief of pain and cicatrization of the ulcerated surface. The treatment prolongs life, and relieves the sufferings of the patient. Even in incurable forms it acts as a most useful palliative.

G. T. Bowen gives the statistics of the General Hospital in Boston for 1903. Of fifty-five cases of epithelioma, twenty-nine were cured. Nine cases which are still under treatment were improved.

On the other hand, four cases of carcinoma of the breast with invasion of the deeper tissues were not benefited by the X-rays.

Williams has treated a considerable number of patients by this method. He thus expresses his opinion of the result of treatment of superficial epithelioma: ‘Further experience teaches us that most small cutaneous cancers of the skin are better treated by the X-rays. Even in the graver forms of inoperable cases they generally will prolong life and diminish pain.’

In the course of a few years the only lesions which will be treated surgically are those intermediate in character between the benign and the inoperable cases. In certain instances it may be advantageous to combine the two methods.

Most superficial neoplasms heal under the influence of the

X-rays. It seems probable that this method will give results as good as those obtained by operation. Time and a careful comparison of statistics will alone show if this is the case. Even if it should be proved that radiotherapy has no superiority over surgical treatment, it still has the great advantage of painlessness, and will therefore always be preferred by most patients.'

In a detailed report made in 1903 by *C. E. Skinner* of Newhaven to the American Electrotherapeutic Association he expresses himself thus:

'It may be affirmed that the X-rays constitute one of the best, if not the very best, means of treating malignant disease.

'At first sight it may be thought that this assertion is in need of justification, but it is based on a number of facts which cannot be gainsaid.

'1. Taking the total number of patients treated, already amounting to several hundred, both with operable and inoperable cases, the proportion of cures is as great as that claimed by any other method. Some authorities assert, doubtless with good reason, that the proportion of cures is even greater.

'2. Only a small proportion of the cases apparently cured have shown signs of relapse. If one compares the recurrence following ablation or cauterization, the superiority of the X-rays is very marked. Moreover, in the vast majority of cases the recurring lesion has yielded to a second series of irradiations.

'3. The cosmetic effect obtained by the X-rays is incomparably superior to that obtained by escharotic or surgical application.

'4. The X-rays almost invariably relieve the pain caused by the cancerous process, without producing any ill effects on the general health.'

Dr. Pusey, in his masterly work on the therapeutics of the X-rays, writes: 'As regards cutaneous carcinoma, unaccompanied by metastasis, there is a long series of well-authenticated cases of success. Radiotherapy can well stand comparison with all other modes of treatment in this respect. Even for cases well within the domain of ordinary treatment, as for instance, in small epitheliomata, the new method defies comparison.'

When one considers the conservative character of this observer, and the qualities which render him so eminent a judge, his opinion acquires a high degree of significance, which is increased when we

find that almost without exception he is in agreement with those who are best able to judge in these matters.

Broers, *Leslie*, *Robert*, *Smith*, *Fergusson*, *Levack*, *Walker*, *Bulkley*, *Hardaway*, *Bronson*, *F. H. Montgomery*, *Gilchrist*, and *Ornsby* all agree that most excellent results are obtainable by this treatment.

Mikulicz and *Fittig* have had good success in cases of epithelioma of the face and in cancer of the breast.

Perthes of Leipzig considers that the X-rays have a specific action on cancer. He gives a résumé of cases published by thirty-five different authors, which shows that the superficial forms of the disease are most amenable to X-ray treatment. His own experience confirms this. He made a careful microscopical examination of a specimen from a recurring cancer which had been treated by X-rays. There was a complete disappearance of the cancer cells.

As regards cancerous lymphatic glands, he finds that they are not influenced by X-rays of feeble penetration, but that irradiation with a hard tube produces a notable decrease in size, and a corresponding alteration in the histological appearance of the glands.

Kienböck, *Freund*, *Holzknecht*, *Scholtz*, *Ehrmann*, *Schiff*, *Gassmann*, *Mackentire*, and *J. de Nobele* have also had satisfactory results, while *Fordyce* has obtained a complete cure in the case of an epithelioma of the nose.

Lassar considers that radiotherapy is of service in the case of cancerous growths, and perhaps in other malignant tumours. He does not however believe that it produces a radical cure, while in some cases it even seems to aggravate the condition.

Lesser has treated five cases of cancer with X-rays, four of which were cured and one greatly improved. One case of epithelioma, cured after three exposures, has not recurred after an interval of five months. *Von Bergmann*, on the other hand, considers that the only efficacious treatment of cancer is extirpation.

Levy-Dorn has reported a case of widespread cancer of the face, grafted on an old lupus of thirty years' duration. It was completely cured after a treatment of nine months' duration by means of the X-rays. At the present time the cicatrix has a healthy appearance, and there is every probability that the cure is permanent.

Kenneth Wills regards the X-rays as exercising a favourable influence on cancer, and he even speaks of their caustic effect. In a total number of 216 cases of rodent ulcer, there has been a com-

plete cure in 141 instances, 43 cases of improvement, 16 in which no alteration has occurred, and 3 in which the condition has been aggravated. This shows a successful result in 65 per cent. of the total number of cases which have been treated.

On the other hand, *Morelle* believes that better results may be obtained by the older methods, especially in superficial epithelioma, where the limitation of the lesion enables us to destroy or remove the whole of the neoformation. The author recommends the curettage of the ulcer, more especially at the edges, followed by complete destruction of the skin by the thermo-cautery. In view of the uncertainty of the action of the X-rays in cutaneous epithelioma, he recommends their employment only in exceptional cases, in inoperable forms, or in very extensive lesions where complete removal is impossible.

Heidingsfeld is of the same opinion, and prefers the use of caustic pastes.

Dr. Henrard of Brussels published two cases of rodent ulcer cured by radiotherapy. In one of these the lesion was situated on the back, a very unusual position.

In France there is but little literature on this subject. In addition to the work of *Vigouroux* and *Cornil*, of *Doumer* and *Lemoine*, of *Mondain* and *Biraud*, on cancer of the breast and other deeper structures, we have the reports of *Chanoz* of Lyons, who has successfully treated some cases of epithelioma, and among others a cancer of the vulva. He writes thus in the *Journal des Practiciens de Lyons*: 'All authorities are unanimous as to the value of radiotherapy in cases of superficial cancer. Numerous photographs taken before and after treatment are conclusive on this point. When the irradiations are properly given, the cells of the neoplasm alone are attacked, leaving the healthy tissue unaffected. This may be seen on microscopical examination. It would seem that some cellular mechanism of which we are ignorant causes the rays to exercise a greater destructive action on cancerous than on normal tissue.'

In 1903, in conjunction with *Drs. Brocq* and *Bisserié*, we presented to the Société de Dermatologie five patients suffering from cutaneous epithelioma. All had been greatly improved by X-ray treatment, and the majority were cured of all objective symptoms. Again in 1904 we showed a second series of cases, accompanied by photographs of the patients.

As long ago as 1903, in all reports of cases we gave exact measurements of the dose used, and we are happy to see that our example in this respect has been followed by later writers.

In February, 1904, *Tuffier*, *Haret*, and *Desfosses* published notes of a patient apparently cured by this procedure. It was a case of epithelioma of the ala of the nose of ten years' duration. Rays of No. 5 penetration were employed. During the first month a dose of 6 H. was given, spread over thirteen séances. During the second month a dose of 16 H. was given in twelve séances. Cicatrization occurred after some delay.

A little later *Dr. Béclère* showed at the Société de Dermatologie several patients affected with neoplasms which had been cured by the X-rays. Some time before this he had obtained successful results both at the hospital and in his private practice, but he hesitated to publish them until he was absolutely certain of their permanence.

More recently still, in June, 1904, at the Société Medicale des Hôpitaux, he showed a case of vegetating epithelioma of the temporo-maxillary region which had been cured by radiotherapy. The patient was a man of seventy years of age, with a cancer of ten years' duration, resulting from a shot wound received twenty-six years before. The lesion was the size of a five-shilling piece.

A microscopical examination by *Dr. Beaujard* showed that it was a lobulated epithelioma. In some places there was a tendency to diffusion and to the formation of epidermic globular aggregations.

The treatment lasted from February 8 to May 2. It consisted of thirteen séances—three during the first week, nine at intervals of a week, and one after a lapse of seventeen days. The doses were 4 H., with the exception of the last two, which were increased to 5 H. Rays of penetration No. 6 were used.

At the present time a hardly visible cicatrix is all that can be seen on the site of the tumour (Plate XIII.).

In order more clearly to demonstrate the special action of the X-rays on the neoplasm, the necrotic action of the rays and all irritative effects were carefully avoided.

'The Roentgen rays in this case,' says *Béclère*, 'appear to have acted in a specific manner, without ulceration or inflammation. They have caused the diminution and regression of a tumour which was continuously progressing up to the time of treatment.

'Pathological experiments had already shown us that the

Roentgen rays, in their irritant and inflammatory action on the skin, did not act primarily on either vessels or nerves, but on the cells themselves. A process of chemical dissociation was set up in the interior of the cells, analogous to that produced on a photographic plate. As a result of this chemical dissociation, cellular lesions occur. It is this cellular lesion which, after a longer or shorter period of latency, provokes the inflammatory phenomena of reaction.

'The therapeutic action of the Roentgen rays is due to the primary cellular lesion, and not to inflammatory reaction, which should in most cases be avoided. The cellular lesion consists in swelling of the nucleus, granular degeneration and destruction of protoplasm. This is shown by lessened reaction to staining reagents. The whole is a process of degeneration, usually terminating in cellular death.

'The primary cellular lesion is rigorously limited to the area irradiated. According to *Kienböck's* law, the degree of this lesion and the severity of the secondary inflammation depend only on the quantity of rays absorbed. Moreover, we find in healthy as well as in diseased tissue a great difference in the sensitiveness of different cells to the rays, so that we may legitimately speak of the selective action of the X-rays.

'As regards normal tissues, the cells of the skin are most sensitive to the Roentgen rays. In diseased states the cells constituting the various neoplasms are by far the most sensitive. In general a tissue is sensitive to irradiation in proportion to its softness, its juiciness, its richness in protoplasm, and the rapidity of its molecular renovation.'

He concludes: 'One cannot doubt for a moment the specific action of the Roentgen rays on epitheliomatous tumours.'

In the early days of radiotherapy *Leredde* was doubtful of its utility. He has, however, lately made a communication to the Academy of Medicine on fifteen cases treated with the X-rays, and his conclusions are strongly in its favour. His work has inspired the inaugural thesis of *Dr. Coriat* on the treatment of cutaneous epithelioma by the X-rays, in which are some observations of interest.

Darier has also reported some successful results.

Bergonié has just published the case of a patient suffering from a cancer of the eyebrow and orbit, which was growing rapidly and

was quite inoperable. The patient was cured by the X-rays, but unfortunately the authors give no information as to the dose absorbed.

At the Congress of Grenoble, in 1904, *Dr. Béclère* read a communication from my friend *Dr. Haret* on some cases of cutaneous epithelioma treated by the X-rays. The results were very satisfactory, and each case was accompanied by a detailed radiodosometric chart.

At the same meeting *M. Reboul*, surgeon to the hospital at Nîmes, reported two cases of cutaneous epithelioma. The following are his remarks: 'The action of Roentgen rays on superficial epithelioma of the skin is undoubted. It should be used in all cases of considerable extent, and in those where ablation is impossible. It is also advisable to submit the patient to a course of radiotherapeutic treatment after operation.'

At the International Congress of Dermatology at Berlin some most interesting cases were exhibited, showing the action of the X-rays on superficial neoplasms.

Good results have been obtained by *Lassar*, *Holzknecht*, *Schiff*, *Béclère*, and *Leredde*, and, in conjunction with *Dr. Bisserié*, we have published a few of our successful cases.

On the other hand, *von Bergmann*, persisting in his original opinion, condemns radiotherapy as a systematic method of treatment, and would reserve it for inoperable cases.

In October, 1904, at the Surgical Congress, *Tuffier* made an interesting report on the radiotherapeutic treatment of cancer. He allows that it has an incontestable effect on cancer of the skin. Amelioration sets in from the eighth to the fifteenth day, and healing is often complete in two months.

It must not be concluded that all cancers should be treated by the X-rays. When a surgical operation can be performed early in the course of the disease, it is in many cases preferable. On the other hand, in widespread cancer of persons beyond middle life the Roentgen rays are to be preferred.

In the foregoing pages I have treated briefly, and I fear incompletely, the main results obtained by radiotherapy in the treatment of epithelioma of the skin.

Reaction.—From what precedes we may conclude that absolutely conclusive results have been obtained by most observers who have tried radiotherapy in the treatment of cutaneous epithelioma.

If, however, we compare the technique employed by different operators, we shall be surprised at the divergence. Some, like *Williams*, prefer rays of feeble penetration, while others, like *Crocker* and *Morton*, employ hard tubes. The duration of the séances, their frequency, and the interval between them, differ according to the operator. Some count by seconds and others by minutes. As to the quantity of rays absorbed, it is generally omitted in the report, although it is the factor of the greatest importance. In France, however, this datum is usually given clearly by such writers as *Tuffier*, *Haret* and *Desfosses*, *Béclère*, *Brocq*, and *Bisserié*.

The mode originally employed was that of *Schiff* and *Freund*, consisting of short séances of a few minutes, repeated two or three times a week, and continued till some change in the appearance of the disease is produced.

The method by means of massive doses, advocated by *Kienböck* of Vienna, and by *Béclère* in France, is getting more universal every day.

According to this method, a dose of 5 H. may be given once a week, as recommended by *Kienböck* and *Béclère*, or once a fortnight, as *Noiré* prefers.

Not only does the method of application vary, but the degree of reaction sought differs with different practitioners.

The severity of the reaction will vary from erythema to necrosis according to the quantity of rays absorbed by the skin.

Pfahler, *Merill* and *Johnson* believe that it is necessary to produce a moderate dermatitis; while others, like *Sjögren* and *Scholtz* in the early days, did not hesitate to set up a violent reaction. *Williams*, *Allen*, *Sweet*, *Léonard*, *Zeisler*, *Campbell*, *Hyde* and *Montgomery*, and *Béclère* have all published cases of cure without any appearance of dermatitis.

Stelwagen believes that a moderate reaction is requisite for cure.

It is difficult to come to a definite conclusion in the midst of these contradictory opinions.

No one method is preferable in all cases. Indeed, there is no such thing as a method for the treatment of cutaneous epithelioma, since all epitheliomata are not similar. The disease exhibits a great variety of forms, both from a clinical and a histological point of view, and its evolution differs greatly in different cases.

It will be necessary, therefore, to study the different types of the

disease, in order to see what forms are amenable to treatment, and what precise method should be adopted in any given case.

Indications for Treatment.—It may be doubted if all forms of cutaneous epithelioma are amenable to treatment by the X-rays. Ought one in all cases of cancer of the skin to proceed at once to radiotherapeutic treatment?

The answer must be in the negative, as in many cases such a course would inevitably fail.

There are many modes of treatment to choose from—the X-rays, cauterization, curetting, surgical ablation, or a mixed treatment of superficial scarification and radiotherapy.

In what conditions is the first of these preferable to all the others? What are the forms which are most readily influenced by the X-rays?

Take, for example, an inoperable case of cancer of the face, with involvement of the bone. In such a case radiotherapeutic treatment must be tried with an intensity corresponding to the severity of the lesion and the rapidity of its growth. The X-rays will probably not effect a cure, but they will cause some amelioration, with diminution of the pain and offensive odour, and in this way act as a most effectual palliative treatment.

A more usual type is epithelioma complicated with affection of the glands. It is often difficult to determine if the glands are cancerous. 'In a case of doubt,' says *Leredde*, 'operative procedure is required. One might indeed treat them by radiotherapy, but it is better to remove them at once by a surgical operation.' Evidently this would be an excellent procedure if its realization were always possible. Most of the glands accompanying an epithelioma may be removed by an operation, but one can never be certain of getting rid of all possible foci of disease.

Moreover, it often happens that when the glands are but slightly affected, the irradiation of the primitive lesion will produce a diminution and disappearance of the glandular enlargement. This fact has been noticed by several authors.

In conjunction with *Bisserié*, we have noticed this phenomenon in several cases of epithelioma accompanied by adenitis.

Whilst in most cases the adenitis is cancerous in its nature, in some it may be only inflammatory. On admittance to hospital, the lesion is usually in a very unhealthy state. It has been treated by all sorts of external medications; it has been irritated,

and often subjected to secondary infection. In consequence an adenopathy has been set up, or a pre-existing one may have been aggravated.

The mere cleansing of the ulcerated surface by aseptic powders or lotions is often followed by a decrease of the enlarged glands. This action may be accelerated by the X-rays, which destroy the offensive odour, increase the discharge, diminish suppurations, and encourage granulation. In this way by merely cleansing the wound they may cause a diminution of the inflamed glands.

On the other hand, by their direct action on the cancerous cells, the X-rays may produce a decrease in size of the enlarged glands.

In conjunction with *Dr. Bisserié*, we had under our care a young woman suffering from recurrence after operation for cancer of the breast. Two of the superficial glands were enlarged, and one somewhat deeper in the axilla. At the commencement of the treatment, the irradiation was directed exclusively on the breast, notwithstanding which the glands in the axilla disappeared at the same time as the nodules on the skin. We have frequently seen carcinomatous glands disappear under direct irradiation of moderate intensity. The fact is corroborated by *Perthes* of Leipzig.

Surgical interference is therefore not of necessity indicated in all cases of cutaneous epithelioma accompanied by adenitis. Moreover, glandular enlargement commonly occurs only in the later stages of the disease, when it has become inoperable. Even when an operation has been performed with removal of the glands, it will be advisable to follow it by a series of exposures in order to diminish the chance of recurrence.

Cancer of the lower lip, which is often accompanied by enlarged glands, is an exception to the above rule. For some unknown reason disease in this situation appears to be but little influenced by the X-rays. The irradiations do not seem to cause cicatrization, and the disease progresses in spite of them. The adenitis too remains stationary. We are not aware if anyone has irradiated the glands directly, but their disappearance would not be of great importance as long as the primary lesion remained unaltered.

The above facts have been noticed in America for some years past by *Pusey*, *Whitte*, *Stelwagen*, and *Gilchrist*; *Hyde* and *Montgomery* have noticed a temporary improvement, followed by a rapid aggravation. *Williams* and *Shepherd* advise recourse to surgical intervention in these cases. Other authors, however, claim

successful results. We have ourselves had but little experience, but in one case of cancer of the lower lip the disease was aggravated rather than improved by radiotherapeutic treatment.

There seems therefore to be something special in cancer of this locality which renders it refractory to treatment.

Perhaps, as *Darier* imagines, our want of success is due to the type of epithelioma which occurs on the lips and mucous membranes. This form, which he calls 'Hornkrebs,' progresses rapidly, and constitutes a morbid type, deep, malignant, and highly infective, which resists all treatment. Hence he recommends early and complete ablation. On this supposition it is difficult to account for the favourable action of the rays in neoplasms of the mucous membrane apparently identical with this affection of the lip. Probably there is some histological difference in the two forms of the disease, but the situation of the lesion renders this very difficult of proof.

It is highly desirable that further experiments should be made on this subject, since it is possible that our want of success is due to some defect in technique.

Meantime it is better to have recourse to complete removal by surgical means, followed by a course of radiotherapeutic treatment commencing eight or ten days after the operation. The dose should be 3 H. or 4 H., repeated at first once a week, and afterwards once in every fortnight or three weeks.

We had under our care a patient from whom an epithelioma of the lower lip had been removed two months previously. There was marked induration of the region operated on, accompanied by some spots of leukoplasia on the lower lip.

After a course of irradiation, the induration completely disappeared, the lip regained its flexibility, the cicatrix became almost invisible, and the leukoplasia completely disappeared.

The form of epithelioma which is most rapidly modified is that which is characterized by a central ulcer covered by a crust, and surrounded by a thickened and prominent border. *Leredde* and *Hallopeau* have given to this variety the name of 'adult epithelioma.' In these cases radiotherapy is without doubt the best method of treatment. The edges rapidly flatten, and the resulting cicatrix is often hardly visible.

The variety of epithelioma with sanious ulceration, with precipitous borders and a hardened base, is rapidly improved, although

PLATE IX.

Before treatment.

After treatment. Total dose, 35 H.

CUTANEOUS EPITHELIOMA (CASE 1).

To face p. 380.

cicatrization occurs more slowly than in the previous variety. Radiotherapy also gives good results when the lesion is a vegetating one, exuberant and invading a large surface. One of two methods may be used. The first is to use intense irradiations, as recommended by *Williams*, in order to destroy the tumour; the cancerous elements are then subsequently cast off like foreign bodies. The other method is to employ a mixed procedure, as described by *Stelwagen*, which consists in using the X-rays together with superficial scarification.

A cure may be obtained by radiotherapy alone even when the lesion is extensive, but the treatment is tedious, especially when all violent reaction is to be avoided.

We are accustomed in these cases to perform a preliminary scarification in order to flatten the growth without removing any of the diseased tissue. We then immediately apply the X-rays, which seem to have a hæmostatic action. In this way we obtain most excellent results in a comparatively short space of time. The cicatrices are very good, hardly visible, and without any retraction, and we know of no other means which will yield results at all comparable with this.

When the tumour is covered with crusts it is better to remove them with the curette. If this is not done, the cure is not so rapid, as the crusts apparently arrest a portion of the radiations. Similar cases treated with and without curetting have given very different results. In one case, a cancer of the nose, we were only successful after removing a large, dry, adherent crust which covered the diseased area.

The last variety which we shall discuss is 'epithelioma perlé.' This may be simple and non-ulcerated, or it may consist of a central ulceration of greater or less extent surrounded by the pearl-like epithelial growths. In these cases it is not easy to ensure a cure by radiotherapy alone. After a few exposures the cicatrization of the ulceration is rapid, and the pearls diminish in volume, but their complete disappearance is very slow. We are therefore in the habit of clearing off the pearl-like growths by means of the curette, and following this by a series of moderate irradiations.

Another factor which has an influence on the choice of treatment is the situation of the epithelioma.

If the lesion occupies the trunk or the limbs one can without

titis; at most a somewhat pronounced erythema is required. The cosmetic results are superior to those obtained by any other process, the cure is usually rapid, and the patient is not obliged to leave his occupation.

In addition to this, the chances of recurrence are less, for the X-rays appear to have a direct and selective action on the elements of the neoplasm, and are therefore less likely to overlook any remaining foci. On this point we may look with assurance to the future for enlightenment.

In any given case the surgeon may often hesitate in the choice of treatment. He must be guided by the situation, the mode of evolution, the form and the appearance of the lesion, remembering that the ulcerated forms of adult epithelioma are the most easily cured.

Method of Treatment.—We must next consider the usual mode of treatment, but this will necessarily vary according to the case.

It depends on the following principles:

1. To cause the absorption in one or two séances of the largest dose which is compatible with the integrity of the tissues.

2. To wait before proceeding further for the phenomena of reaction to appear, and if these are violent to wait further until they disappear.

In a case of epitheliomatous ulcer with raised margin, we may give a dose of 8 H. to 10 H. in one or two consecutive séances. The irradiation should include a margin of healthy skin at least 5 millimetres in breadth. If the lesion is in one of the more sensitive regions, such as the nose, it is wiser not to exceed a dose of 7 H. or 8 H. with rays corresponding to No. 5 or No. 6 on Benoist's scale. The patient is told to return in a fortnight or three weeks' time. After this interval the treatment is continued, or we may await the further evolution of the reactive phenomena. As a rule, we shall find that the ulceration has already diminished, and the inflammation is lessened. A second dose of 7 H. to 9 H. is then given, followed by another interval of a fortnight or three weeks. After this, a third exposure may be given if the state of the skin permits it, this time with a smaller dose of 5 H. or 6 H. if the lesion is in a state of regression.

If the lesion is stationary, we may give 8 H. or 9 H., and so on, gradually diminishing the dose as the disease disappears, and the

reaction becomes more marked. It may be noted that ulcerated epitheliomata easily bear an exposure of 8 H. or 9 H., and that in our experience a violent reaction is quite exceptional.

In cases where curetting precedes the radiotherapeutic treatment, we proceed as follows: The vegetating surface is levelled by means of the curette, but it is not necessary to follow the deeper prolongations of the disease. After four or five days the first irradiation may be given, with a dose of 8 H. or 10 H., which is perfectly well borne by a surface denuded of integument. After two or three weeks a second irradiation with the same dose may be given, after which decreasing doses succeed until cicatrization is complete. The region is treated with a thick paste of zinc, and the skin is sprayed before each irradiation.

By this means we cured a large epithelioma involving the nose and lower eyelid. The improvement was rapid, the treatment lasting about three months, with a total dose of only 35 H. The cosmetic result was perfect. The lower lid, which before the treatment was somewhat ectropic, is now quite normal. It is certain that no other mode of treatment would have given equally good results (Plate IX.).

When we have to treat a cutaneous epithelioma which is not ulcerated, or one which has recurred after operation, the mode of procedure is somewhat different. Two methods are at our disposal.

The first consists in the exhibition of a dose of 7 H. to 8 H. in one séance, with an interval of a fortnight or three weeks before proceeding further. The reaction may be rather violent, increasing from erythema to ulceration.

This inflammatory reaction is not necessary, as some authors assert, but it is very difficult to avoid it. Like a stomatitis occurring during the course of mercurial treatment, it is an accident due to too large a dose. It must not be assumed that it is to be avoided in every case. In a severe and rapidly-progressing case of syphilis, we should not be deterred from continuing the treatment by signs of mercurial intoxication. Just so with radiotherapy. We recognise the danger of slight dermatitis, and we know how to avoid it; but the lesion may require for its cure a massive dose, greater than the skin will bear without reaction. We may disregard the danger to the integument if the case requires it.

There are, in fact, some cases of epithelioma which remain stationary under a dose of 3 H. or 4 H., and which begin to im-

PLATE XI.

Before treatment.

After treatment. Rays, Nos. 5 and 6 ; total dose, 36 H.
CUTANEOUS EPITHELIOMA (CASE 3).

To face p. 384.

prove at once when the dose is raised to 7 H. or 8 H. We have had many cases which prove this conclusively.

We are far from advising the use of radiotherapy as a caustic agent; we do not consider that ulceration or sloughing is required for the cure of epithelioma. But in order to obtain a rapid and definite result, we may in certain cases prescribe a dose of 7 H. or 8 H., a quantity capable of producing a severe erythema, which may be followed by excoriation.

The second method consists in the irradiation of the lesion every week or ten days with a dose of 4 H. or 5 H. This procedure gives excellent results, but is frequently insufficient.

It has the disadvantage of not leaving an interval between two successive exposures long enough to allow of the complete evolution of the reaction, so that it is difficult to estimate the exact dose which should be given during the next séance. This method, therefore, requires a good deal of skill and experience on the part of the operator.

The following are the usual phenomena of reparation:

One of the first results of treatment is the rapid diminution of pain, followed by its complete cessation in the course of a few weeks.

Next, any ulceration that may exist is modified. The sanious, yellow, weeping surface changes its appearance, and the discharge at first is increased. This fact, which was noticed by *Leredde*, is almost constant, particularly in cases where the ulceration is surrounded by a raised border. The patients say that the wound weeps a great deal. This is due either to an inflammatory reaction set up by the X-rays or to the disintegration of the carcinomatous cells, the juice of which is eliminated by the discharge. At the same time there is a diminution of the fœtid odour which characterizes the disease. The raised margin disappears, the ulcer contracts, and the whole lesion becomes softer. In hæmorrhagic cases the tendency to bleeding ceases. One can, as *Leredde* says, see the reparation proceeding under one's very eyes.

When the lesion is covered with crusts, these at first become thicker and more numerous, but afterwards fall off. New crusts are formed, but these are thinner in texture. They in turn fall off more easily, and this is repeated until at last they cease to be reproduced.

In cases where the ulceration is deeper, with sharply-cut borders,

it is interesting to see the base of the ulcer granulate and become gradually raised till it reaches the level of the skin, at last giving rise to a cicatrix which is hardly visible. The results from a cosmetic point of view are most admirable, and far superior to those furnished by cauterization or other surgical operation.

Accidental Reaction.—Radiotherapy has been accused of producing serious accidents. Most of the cases reported, however, have followed the irradiation of deep-seated neoplasms. They are quite exceptional in the treatment of epithelioma of the skin. Nevertheless, we agree with *C. V. Allen*, *Taylor*, *Lassar*, *Oudin* and others, that radiotherapy may in certain cases occasion an aggravation of the morbid phenomena, or even an extension of the carcinomatous foci.

Instances have been reported of the occurrence of epithelial tumours on the cicatrices following dermatitis, and we have already alluded to the development of neoplastic growth on the hands of operators suffering from chronic dermatitis. Thus the X-rays, which usually cause the regression of neoplastic growths, may in certain exceptional cases determine their production.

While allowing the accuracy of these assertions, we do not see any contra-indication for radiotherapeutic treatment.

It must be remembered that other cicatrices besides those which follow radiodermatitis may be the starting-point for malignant growths. Cutaneous cancer may be developed on an ordinary scar, which forms for the moment a point of least resistance.

The accidents which sometimes occur to the hands of operators do not affect the point under discussion. They are due to the daily absorption of minute doses of the rays, and require years of exposure for their production. They are out of the question in the ordinary course of treatment.

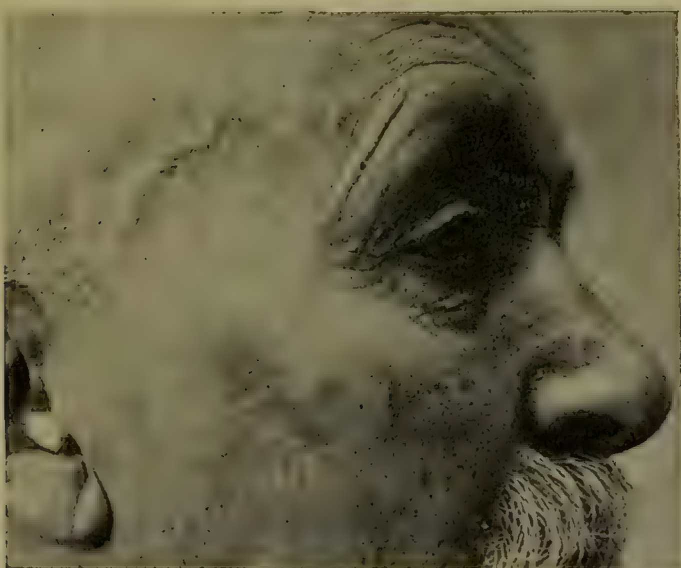
The septic infection due to absorption of cancerous débris is only possible when the lesion occupies a considerable surface, or has invaded the deeper layers. This is never the case with cutaneous epithelioma.

In the whole course of our radiotherapeutic practice we have never seen a case of intoxication from this cause, nor have we observed any complication of the general health among the many cases of cutaneous epithelioma which we have treated.

All our cases treated by this method have been improved, and most of them have been cured, while a few are still under treat-

PLATE XII.

Before treatment.



After treatment. Rays, Nos. 5 or 6 ; total dose, 30 H.

CUTANEOUS EPITHELIOMA (CASE 4).

To face p. 386.

ment. In 1903-1904 we treated 27 cases of epithelioma of the skin at the Broca Hospital. Of these, 15 were apparently cured, 7 were improved, and 8 are still under treatment, while 4 have left off attending the hospital. The total dose absorbed by each patient was 20 H. to 45 H. We have had only one case of recurrence, and this yielded promptly to a second series of irradiations.

It will be seen that the percentage of successes is very satisfactory. In most cases the patients were completely cured by a month's treatment.

As regards the permanency of cure, the statistics which have appeared up to the present time are most encouraging. But are we yet justified in forming a very optimistic opinion on the value of radiotherapy? We have not had sufficient length of experience to say. When the patients apparently cured have remained so for four or five years, it will be time enough to answer this question.

Meantime, we do not assert that cancer of the skin can be permanently cured by this method. What we do affirm is that radiotherapy temporarily removes the objective symptoms of nearly all cutaneous neoplasms, that the cicatrices are most satisfactory, and that the chances of recurrence are less than in any other mode of procedure.

Cancer of the Tongue and Mucous Membrane.

We have already touched on the lack of success in the treatment of the lip by X-rays. We shall not return to the subject.

Cancer of the Tongue.—*Engmann* and *Ascher Silva* have each reported a cure of cancer of the tongue by this method. It is unfortunate that no histological examination was made in either of these cases.

Dickson has obtained considerable amelioration, but the results are usually much inferior to those obtainable in cutaneous cancers. *Startin* has also reported the regression and cicatrization of an ulcerated epithelioma of the tongue.

Perthes of Leipzig did not obtain good results in cancers of the tongue and of the floor of the mouth.

Probably the action of the rays is different on various types of the disease. *Leredde* has some interesting remarks on this subject. A case came under his treatment suffering from vegetative epithelioma of the tongue, on which there were three distinct foci of the

disease. One was papillomatous, without any adventitious covering, while the other two were covered with a horny layer. Irradiation was directed on all three lesions at the same time. After two or three séances, the lesion first described was diminished, and the epithelial tissue disintegrated, whereas the other tumours resisted the action of the rays, and remained unaltered even after several exposures.

In June, 1904, *Bisserié* communicated to the Academy of Medicine two cases of cancer of the tongue cured by the X-rays.

The patients had been examined by *Sabouraud*, *Brocq*, and *Tillaux*; the diagnosis therefore admitted of no doubt.

One of these presented on the back of the tongue a tumour of the size of a bean, with an indurated base. There was also a leucoplasia with induration of the dorsum of the tongue, with a hard and swollen submaxillary gland. The patient suffered severe pain.

After a few exposures the tumour and the leucoplasia entirely disappeared, and the tongue regained its normal flexibility.

A second patient presented a tumour the size of a sixpence, with induration of the whole tongue, accompanied by terrible pain in the tongue and ear. After two months' treatment, consisting of three exposures, the tongue regained its normal appearance.

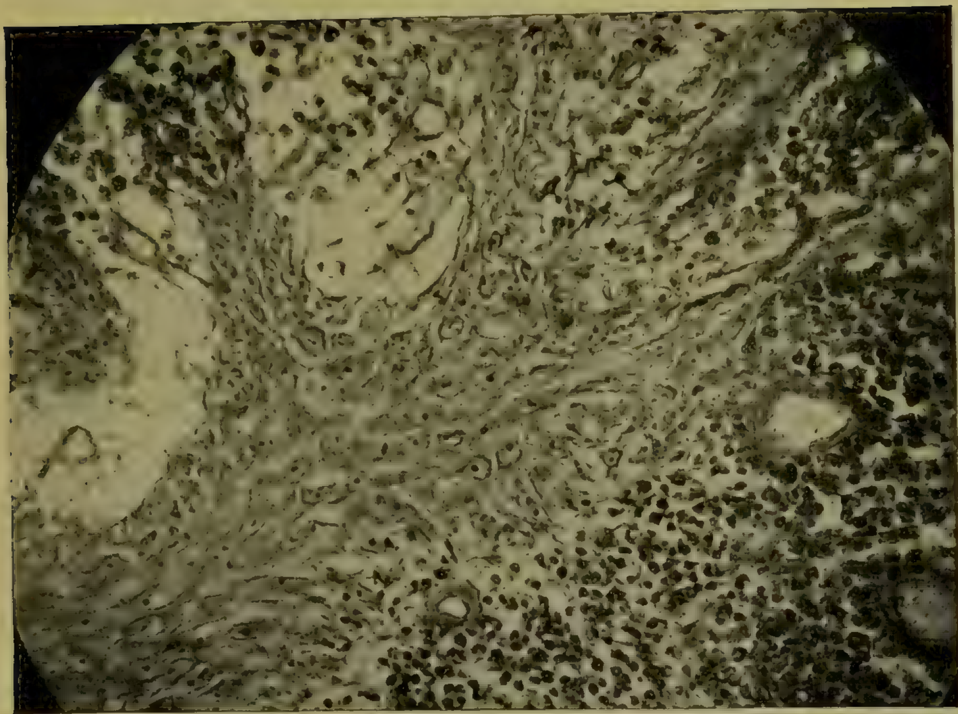
Without affirming the permanence of the cure, the author may yet congratulate himself on having secured so good a result, especially when we consider the malignancy of lesions in this situation. It is unfortunate that no microscopical examination was made of the lesion.

At the Congress of Grenoble *Reboul* reported the case of a female patient of fifty-five with epithelioma of the tongue, which involved the corresponding pillar of the fauces. The treatment was not followed by success. The pain was diminished by the first irradiation, but after the third exposure the tumour increased, and the treatment was abandoned.

Dr. Béclère exhibited at the Berlin Congress the cast of a tongue attacked with a vegetating epithelioma, which had been cured by radiotherapy. A cast of the tongue taken after treatment showed an organ which was absolutely intact. The microscopical examination made at the commencement of treatment confirmed the diagnosis.

We have ourselves treated several cases of cancer of the tongue,

PLATE XIII.



Microphotograph of a section. showing the excavation of the mucous membrane.

Photograph of two casts taken before and after treatment. Rays, No. 6 ; total dose, 54 H.

CUTANEOUS EPITHELIOMA.

(Contributed by Dr. Béclère, of the Saint Antoine Hospital.)

To face p. 388.

with varying results. In most of the cases a large portion of the tongue was affected, and the glands were enlarged.

In every instance we noticed a marked diminution in the painful symptoms. In some cases the leucoplasia disappeared, and the tongue became softer, without, however, any sensible diminution in the size of the tumour. In one instance, that of a large epithelioma on the under surface of the tongue, there was a sensible diminution of the tumour. After a time, however, the tongue became hard and covered with white patches, with erosion and hypertrophy of the papillæ. In this case, which was quite inoperable, it may be doubted if the X-rays produced any favourable effect.

In another case the history is interesting as illustrating the choice of treatment.

The patient was a man with a history of syphilis. He had on the edge of the tongue a small, hard, protruding tumour the size of a pea. We saw the case in the country, and made the diagnosis of epithelioma, which was confirmed later on by *Dr. Brocq.*

We determined to remove it by surgical means, and to irradiate the scar. The patient, however, consulted a specialist, who ordered him a course of mercurial treatment, although a previous one had been without result.

The patient grew worse, and when we saw him again he had a typical epithelioma of the tip of the tongue. This was slightly ulcerated, of the size of a sixpence, and level with the surface.

The lesion was removed by an operation, without much loss of substance, as may be seen from the appearance of the tongue.

A microscopical examination confirmed the diagnosis.

The healing was slow, and there remained a spot of doubtful aspect at the end of the tongue, which bled freely.

One month after operation an irradiation of 4 H. to 6 H. was given, and this was repeated every fortnight.

At the present time there is no sign of recurrence, although the operation dates back to June last. There is no pain, the tongue is soft, and the scar is barely visible. The suspicious spot has regained its normal appearance, and we have every reason to hope for a permanent cure. Irradiations at intervals of a fortnight are still continued.

From these observations it is evident that a favourable result may be obtained in certain cases of epithelioma of the tongue,

where the lesion is well delineated, and not accompanied by metastases. It is well to bear in mind, however, the gravity of the disease in this situation, and the difficulty of irradiation.

When possible, especially if the growth is of a considerable size, it is wise to combine surgical treatment with radiotherapy. The two methods are not antagonistic. 'Radio-chirurgical' treatment, as *Béclère* calls it, is often of inestimable advantage to the patient.

When there is no enlargement of glands, and the lesion is small, hard, nodular, and easily bleeding, it should, without doubt, be removed by a surgical operation. The loss of substance is small, and the result rapid. After cicatrization, or even before it is completed, the site of the lesion should be irradiated. The exposures will hasten cicatrization if that is incomplete, and cause the absorption of any diseased cells which may have remained behind, and which form foci for a recurrence of the disease.

In operable cases of a more serious nature, one should take into consideration the age of the patient, the condition of his nervous system, and the possibility of removing the whole of the disease. In this case a preliminary surgical operation is indicated, followed by a course of radiotherapeutic treatment.

In inoperable cases, or in cases where an operation would result in excessive mutilation, radiotherapy is to be preferred. It is much more acceptable to the patient, and even if they do not cure the analgesic action of the X-rays makes them an excellent palliative.

It is difficult to irradiate the tongue successfully so as to act thoroughly on the diseased portion without affecting the rest of the mouth. In our earlier attempts we endeavoured to draw the tongue out of the mouth by a pair of forceps of special construction, while protecting the rest of the mouth with a lead shield. This plan was not successful, as the patient could not bear the pain for more than a few minutes.

With the use of a localizer the treatment is much simplified. A tube of suitable size is introduced into the mouth, and the patient is directed to place the tongue in the required position against the aperture. In this way fairly long exposures may be made without much fatigue.

We have had some localizer tubes made, in which the plane of the aperture is oblique, so as to be able to reach all parts of the mouth. The only objection to their use is that the irradiation is

not equable over the whole surface. The convenience of the method, however, far overbalances this disadvantage.

These localizer tubes are, in our opinion, much superior to the special focus-tubes designed by *Oudin.* These are very expensive, and only of use in certain cases. The intensity of irradiation is just the same with the localizer and with the special focus-tube, since it depends only on the position of the anticathode in respect to the irradiated area. In the special tubes the anticathode is placed at the centre of the tube, and a cylindrical prolongation gives exit to the rays at its extremity only. To have any real advantage, this tube should be constructed so that the anticathode can be brought into close proximity to the diseased area. The results are exactly the same, whether the conducting tube be part of the focus-tube, as in the special form, or attached to it as a localizer. The latter has the further advantage of simplicity, solidity, economy, and adaptability to all the cavities of the body. Lesions of the face, the cheeks, the uterus, the rectum, and the nasal fossæ may be easily treated by its means.

In the treatment of cancer of the tongue the rays should be No. 6 or No 8 on Benoist's scale, varying in penetration according to the size of the tumour.

It is difficult to prescribe the quantity of rays which should be given, in consequence of the varying aspect of the lesions we are called on to treat.

As it is of importance to avoid reaction, we should not exceed 4 H. or 5 H. for each application. We have never had a serious inflammatory reaction. *Bisserié* used the same procedure in the cases treated by him. A period of twelve to fifteen days should intervene between consecutive exposures.

Cancer of the Uvula and Palate.—*Mecaw* has reported a case of primitive cancer of the uvula and soft palate, which was cured by excision and subsequent irradiation. *Professor Ehrmann* and *Freund* obtained a remarkable amelioration in a case of epithelioma of the palate. What we have said of cancer of the tongue applies equally to these cases, but in our opinion an operation should precede radiotherapeutic treatment whenever possible.

Cancer of the Larynx.—*Morton* treated a case of this disease sent to him by *Delavan.* The patient improved, but ultimately died of Bright's disease.

Scheppegrell reported a case of cancer of the larynx cured after

twenty séances. No trace of the tumour remained, and all the clinical signs had disappeared.

Dr. Massier of Nice published a case of inoperable cancer of the larynx in which the favourable action of the X-rays was most marked. *Béclère* has cured a patient affected with cancer of the larynx. The diagnosis had been made successively by *Chauffard*, *Launay*, and *Violet*, but there was no microscopical examination. The clinical signs and the laryngoscopic examination were, however, both in favour of a neoplasm.

The patient was under *Dr. Béclère's* care for five months, from November 25 to April 22, 1904. During this period he was submitted to four series of ten to twenty exposures of ten minutes each, or a total of sixty séances.

One month after the commencement of treatment there was a notable change in the tumour, which appeared to be modifying, a large portion being ulcerated.

In three months the tumour had almost disappeared, and ultimately a complete cure was obtained.

During the treatment the patient gained 16 pounds in weight. He now swallows all sorts of nourishment without difficulty. He can swallow as well as he used to, is his own expression. His voice has returned completely, and in spite of the paralysis on the left side, which still continues, the patient has a clear and powerful voice.

Even if we remain in some doubt as to the diagnosis, which was confirmed by several observers, we must still allow that the laryngeal mucous membrane can be modified by an irradiation through the cartilaginous framework and the muscles of the larynx.

The irradiation of the larynx may be carried out in two ways.

We may endeavour to irradiate it directly by means of a specially designed focus-tube, whose anticathode is at the extremity of a prolongation which may be introduced into the throat.

Without taking into consideration the difficulty of construction, it seems almost impossible that the patient should support such a tube in the mouth for so long a period.

It is useless to endeavour to reflect a beam of rays into the larynx, for it is well known that the Roentgen rays are not capable of reflection.

Only one method is at our disposal—viz., to irradiate the disease through the tissues which cover it. This is the procedure adopted by *Béclère.*

The quantity of irradiation given should be the greatest possible without setting up a reaction severe enough to hinder the further treatment.

Fairly penetrating rays should be used, corresponding to No. 9 or No. 10 on Benoist's radiochromometer. If necessary, the neck may be covered by a thin leaf of aluminium in order to absorb the less penetrating and more noxious rays. The focus-tube should be placed at some distance, so as to equalize the quantity of rays absorbed by the deeper portion of the tumour to that absorbed by the skin. Under these conditions the time of exposure will of necessity be much longer.

It will be advisable to irradiate the front of the neck and each side in succession. Each region should receive a dose of 5 H. In this way the tumour will absorb a dose proportional to 15 H., since it has been irradiated from three sides. From this estimate a certain amount must be deducted in consequence of absorption by the skin, the muscles, and cartilages.

The exposure may be repeated once a week at first. The dose must be reduced to 4 H. if there are signs of reaction, or the séances may be at longer intervals.

Although there is no certainty of success, radiotherapeutic treatment should be attempted in cases where an operation is impossible.

CASES OF CUTANEOUS EPITHELIOMA.

Case I.—M. P., aged thirty-five. The patient was sent to us from the country with a vegetating epithelioma of the internal angle of the left eyelid. It extended to the nose and invaded the alæ. The lower eyelid is attacked and slightly ectropic.

Plate VIII. represents the appearance of the disease.

As the tumour was of considerable size, the treatment was commenced by scraping. Only the superficial portion was removed. Ten days after the operation irradiation was commenced, the eye and the rest of the face being carefully protected.

Rays of penetration No. 5 were employed.

December 10 *and* 11, 1903.—Dose of 9 H. in two séances.

December 24.—No violent reaction ; a slightly erythematous zone round the ulceration. The patient feels better.

Dose of 9 H.

January 6, 1904.—Cicatrization is advanced; there is no pain; there is still an ulcerated spot in the centre, which is again irradiated.

Dose, 3 H.

January 21.—Cicatrization is almost complete; there is still a small ulcer, the size of a lentil, at the inner angle of the eye. The cicatrix is healthy. The lower lid, which had not been scraped, is improved.

Dose, 4 H.

February 5.—There are some suspicious spots on the root of the nose, at the angle of the eye, and on the lower lid. These had not been curetted, and were shielded from the X-rays by the lead mask. They are now slightly scraped, and immediately afterwards exposed to the rays.

Dose, 8 H.

February 16.—The irradiated skin is in reaction, and bright red. Healing continues.

February 26.—Cicatrization is complete. There are no signs of activity. The scar is healthy. The ectropin has disappeared. (Plate VIII.)

To prevent recurrence a final exposure is given, and the patient is discharged.

Dose, 5 H.

In this case the rapidity of the result and the satisfactory appearance of the scar were greatly due to the radiotherapeutic treatment. The scraping was quite superficial, and did not remove the diseased tissue.

Case II.—Mme. M., aged sixty-eight. Epithelioma of the left cheek, ulcerated, with hard edges, sharply excavated, but without raised margins The base is indurated. There is a good deal of itching. The ulcer commenced a year ago after an accident. (Plate XI.)

December 24, 1903.—Séance of twenty minutes; rays, Nos. 4 to 5; dose, 5 H. to 6 H.

December 25.—Second séance of fifteen minutes; dose, 4 H.

January 11, 1904.—The ulceration has improved in appearance; it is not so hard, and the itching has diminished. There is only slight reaction.

Séance of twenty minutes; dose, 5 H. to 6 H.

January 12.—Séance of fifteen minutes; dose, 4 H.

January 29.—No noticeable reaction; the ulceration and hardness have diminished. There is marked improvement.

Séance of fifteen minutes; dose, 4 H.

January 30.—Séance of twenty-five minutes; dose, 5 H. to 6 H.

February 15.—The ulcer is almost healed; there only remains a crusted patch the size of a lentil. The crust is at the bottom of a depression, resting on a base which is still indurated. The irradiated skin is still red. The aperture in the mask is diminished so as to allow the rays to act only on the diseased spot.

Séance of fifteen minutes; dose, 4 H.

February 16.—Séance of fifteen minutes; dose, 4 H.

March 1.—The ulcer is healed; some redness and itching remain. The site of the ulcer is still harder than the parts adjacent.

The treatment is suspended, as there is considerable reaction.

February 28.—A small projecting crust has made its appearance at the centre. The base is not so hard.

Séance of fifteen minutes ; dose, 4 H.

April 28.—The scar is very satisfactory in appearance ; there are no crusts, and the patient is apparently cured. A slight depression shows the site of the former lesion. The skin looks healthy, and the induration has greatly diminished. (Plate X.)

Séance of ten minutes with more penetrating rays (No. 7), in order to act on the deeper tissues and prevent recurrence.

Dose, 3 H.

This patient was shown to the Société de Dermatologie.

Case III.—Mlle. V. Epithelioma of the nose extending over the left cheek, and involving the ala of the nose ; serpiginous, with numerous crusts, vesicles, and phlyctenulæ, with serous discharge.

The disease began thirteen years ago. It was treated by scraping and the actual cautery. Subsequently the patient was treated by phototherapy by *Dr. Leredde*, coming up from the country for each séance.

October 14.—The patient came under my care.

Séance of twenty minutes ; rays, No. 4.

Equivalent spark, 2½ centimetres ; electrical constants, 16 volts and 4 ampères.

Dose, 4 H.

October 15.—Second exposure similar to the first. Dose, 4 H.

October 24 *to* 25.—No great change.

Dose, 6 H., in two séances, each of twenty minutes' duration.

November 6.—The phlyctenulæ have disappeared. The lesion has dried up : it is red in colour, with white patches. At the extremity of the nose and around the ulcer some crusts still remain, with sero-purulent discharge.

Only one séance is given.

Dose, 4 H.

November 24.—The patient is very pleased with the improvement. The crusts have come off—even those from the tip of the nose, which was exceeding painful. The phlyctenulæ have disappeared. A few crusts appear around the lesion.

Dose, 4 H. to 5 H.

November 25.—A second séance ; dose, 3 H. to 4 H.

There was some redness after the exposure on November 24, probably a pseudo-reaction.

December 9.—The reaction has been excessive, and is still very pronounced. New crusts have formed, but less abundantly. The nose is red, and has the appearance of lupus. A few phlyctenulæ are to be seen. These frequently made their appearance even before the commencement of the irradiations.

January 4, 1904.—The reaction has quieted down ; the skin has a cicatricial appearance. *Dr. Brocq*, who examined the patient, considered the case as completely cured, with a most satisfactory result as far as appearance is concerned. The patient was photographed.

January 28.—Two or three white pearl-like structures are to be seen at the

internal angle of the eye. These had been covered by the lead mask. They are irradiated in two séances of fifteen minutes' and ten minutes' duration.

Dose, 8 H.

April 1.—The cure is complete. (Plate XI.)

The patient was shown on two occasions to the Société de Dermatologie.

Case IV.—M. F., aged sixty-six. Cutaneous epithelioma of the temporal region of a concrete seborrhœic type. Has been treated for a year by phototherapy without result.

From January 13 to March 14 the patient received four exposures with No. 5 rays, and doses of 8 H., 4 H., 5 H., and 3 H.

Plate XII. shows the result of the treatment.

Case V.—Mme. J. J., aged fifty-five. Epithelioma commencing at the side of the nose, of the size of a crown-piece. Has destroyed the back of the nostril and invaded the cheek. The centre is cicatricial, and the edges are spreading, with an elevated border and pearl-like nodules, with a few ulcerated and bleeding glands.

August 14, 1903.—First exposure with No. 5 rays; dose, 6 H.

August 21.—Considerable improvement; the ulcerated and bleeding points have disappeared. Most of the crusts have fallen off.

September 11.—A few epitheliomatous points still remain, but these have not spread. The ulceration on the ala of the nose has returned to a small extent. The rest of the surface is improved.

From this date till November 27 the patient had five or six séances at irregular intervals, with a total dose of 24 H.

November 27.—The general appearance has improved. A few nodules and some crusts are to be seen on the lower lip and at the margin of the nostrils.

Dose, 5 H.

November 28.—Dose, 3 H.

December 12.—There is still some reaction of the nose. Some crusts remain on the side of the nose, and nodules in the vicinity of the lip.

Dose, 5 H.

January 4, 1904.—The crusts and nodules have disappeared after a sharp reaction. The treatment is suspended till the reaction has ceased.

March 24.—The patient only returned after an interval of over two months. There is a yellow crust on the side of the nose, and a small ulcerated point at the commissure of the upper lip. The nose is slightly painful.

Dose, 6 H.

April 15.—The part which was irradiated is improved. On the right side of the nose a small induration covered by a crust has made its appearance. An intense irradiation was given.

May 7.—There has been a sharp reaction with discharge, followed by the formation of crusts, and some pain.

A greasy crust has formed on the dorsum of the nose. This was lightly scraped and irradiated.

Dose, 6 H.

The patient is still under treatment. The result is good, although not perfect. The lesion was a very severe one, and the treatment had to be interrupted more than once on account of ill-health.

Case VI.—Mme. P., aged sixty-five. Epithelial nodule on the side of the nose. The lesion is of the size and appearance of half a pea, and is of two years' duration. Has been treated by scraping without success.

Five series of exposures were given between September 12 and October 20, 1903. Dose, 7 H. to 8 H. in each series of two exposures.

October 20.—The nodule was diminished considerably in size. The patient did not continue the treatment.

Case VII.—Mme. B., aged fifty-six. Epithelioma on the forehead. The lesion commenced sixteen years ago by a small pimple.

A microscopic examination was made by *Dr. Lenglet*, with the result that the lesion was found to be an epithelioma.

The disease is the size of a crown-piece, and is situated on the median line of the forehead. The skin is atrophic and shining, and ulcerated in places. A few scales are to be seen.

October 31, 1903.—Dose of 4 H. with No. 5 rays.

November 2.—Dose of 2 H.

November 16.—Dose of 5 H.

November 17.—Dose of 3 H.

November 28.—Improvement; marked redness or reaction. The nodules are fading away.

January 17, 1904.—Dose of 4 H.

January 18.—Dose of 8 H.

February 5.—There is no trace of the lesion, but the region is still red. The irradiations were of slight intensity, in consequence of the sensitiveness of the skin of the forehead.

The patient was shown to the Société de Dermatologie.

Case VIII.—M. B., aged sixty-three. Epithelioma of the right ala of the nose, consisting of a hard nodule the size of a haricot-bean.

From October 3 to January 15, 1904, the patient had six series, each of two exposures, with a dose of 6 H. to 8 H., giving a total dose of 45 H. Rays No. 5 were employed, and the reaction was at times considerable.

December 8.—The lesion was reduced to the size of a pin's head.

December 15.—The patient was completely cured.

Case IX.—M. B., aged seventy-five. On the left eyebrow there is an enormous vegetating epithelioma 10 centimetres in diameter and 2 centimetres thick. This commenced six years ago. The centre of the lesion is slightly depressed and the edges are raised. The lesion is painful, with some discharges and occasional hæmorrhage. The general health is good; the left eye is covered by the tumours.

From November 17 to December 9 he had a dose of 12 H., with rays No. 6.

November 20.—The tumour is diminished in size. The eye is visible. Reaction is moderate.

Dose, 5 H.

November 21. — The pain is considerably lessened. The patient sleeps well.

Dose, 5 H.

The patient left the hospital.

This case only shows a certain diminution of the tumour. The result might have been better if the patient had continued treatment. He was a countryman and was tired of Paris.

Case X.—M. B., aged eighty. Epithelioma of the nose. The lesion commenced fifteen or twenty years ago by the appearance of a small hard nodule on the dorsum of the nose, which bled easily.

A surgical operation was performed five years ago. There was no recurrence for three years.

Two years ago a hard nodule appeared on the left ala of the nose. At the present time there is a small ulceration with hardened edges, 5 centimetres long and 1 centimetre in width. It bleeds freely, and the whole nose is covered with telangiectases and is of an unhealthy appearance. The case is almost inoperable.

The patient complains of pain. The case has been treated with caustics without result.

June 4, 1903.—The diseased area is exposed to the X-rays, the rest of the nose being shielded by a sheet of lead.

Rays, No. 5. The left ala of the nose is irradiated.

Dose, 5 H.

June 5.—The pain is less and the nose is less sensitive.

Dose, 4 H.

June 11.—There is no pain. The lesion is redder and there is a serous discharge; reaction has begun. The treatment is suspended.

June 23.—The irradiated area is still in reaction; the discharge has increased.

July 2.—There is but little serous discharge; the crusts are diminished; the centre is depressed and of a yellow colour; the raised edge is flattened.

July 9.—The lesion is healed; nothing remains but a few crusts around the periphery. The patient is very pleased with the result; there is no pain.

As the nose is still hard, and has a suspicious spot near the tip, an irradiation is given to the whole nose, the normal incident rays being directed on the cicatrix.

Dose, 4 H.

July 23.—The condition is improved; the nose is softer; here and there are a few crusts, which seem to be foci for new epitheliomatous growths. An irradiation of the whole nose is given.

Dose, 4 H.

July 29.—The condition is stationary; a new crust has formed on the cicatrix, which is again irradiated.

Dose, 4 H.

A second irradiation is directed to the tip of the nose, where there is a growing lesion.

Dose, 5 H.

October 28.—The end of the nose is still diseased.

Dose, 9 H.

November 16.—The region which was last irradiated is slightly ulcerated and weeping; the ala of the nose is quite healed; the whole nose has an unhealthy appearance.

Dose, 4 H.

November 17.—The whole nose is again irradiated.

Dose, 5 H.

December 5.—The nose is of a reddish-violet colour, with here and there a few small vesicles. The tip of the nose is ulcerated, but the epithelial growth has disappeared; there is still a good deal of reaction.

December 12.—The ulceration of the tip of the nose persists; the whole is less red; the lesion on the ala is healed.

January 16, 1904.—The nose looks well; nothing remains except a small crust on the tip of the nose. *Dr. Brocq*, who examined the patient, advised the treatment of the cicatrix, which was of a keloid appearance and covered by telangiectases.

Dose, 4 H.

March 18.—A short irradiation is given to the tip of the nose.

Dose, 4 H.

April 7.—A small crust has made its appearance on the left side on the site of the original lesion.

Dose, 5 H.

May 20.—An irradiation of the whole nose is given to prevent recurrence.

Dose, 5 H.

The patient was told to return every month to be watched. The case cannot therefore be considered as permanently cured, although it is greatly improved.

The patient was shown to the Société de Dermatologie.

Case XI.—Mme. L., aged forty-one. Cutaneous cancer of the left ala of the nose, of eight years' duration.

The patient suffers from diabetes. For many months she has been treated by *Czerny's* method, with slight improvement after three months' treatment. After this there was a recurrence and extension of the disease.

At the present time there is an ulcerated epithelioma, with sanious base and hard border, which is raised at one point. The ulcer, which is 1¼ centimetres in diameter, is increasing in size.

The irradiation is given with our installation, driven by a Ruhmkorff coil. Rays of penetration, No. 5 of Benoist's radiochromometer are employed.

July 16.—Dose, 4 H.

July 31.—There is some improvement; the discharge is increased and healing has commenced; the edges are lower, especially in the more projecting portions; there is slight reaction.

Dose, 4 H.

August 21.—The improvement continues; the healing is complete; the projecting point is smaller, but there remains a raised line round the periphery.

September 11.—The raised edge is no longer visible; the site of the lesion is only marked by a few hard papillæ; the epitheliomatous nodule is much smaller.

Dose, 8 H.

October 10.—The aspect of the lesion is good; the nodule still subsists.

Dose, 8 H.

November 6.—The skin is normal; the nodule still persists.

Dose, 8 H.

November 23.—The skin is red, and the nodule is diminished in size. On the edge of the diseased area two or three pearl-like excrescences are to be seen.

Dose, 6 H.

November 24.—The skin is red, and the patient complained of itching after the irradiation of yesterday. This is a case of pseudo-reaction. Two exposures are given.

Dose, 3 H.

December 9.—There is sharp reaction, with pronounced erythema and pain. The nodules and pearls are hardly visible. The treatment is interrupted for a time.

January 25.—The inflammation has subsided, but there still remains a small indurated point, which is irradiated.

Dose, 6 H.

February 16.—The reaction has not been marked. A longer exposure is given in order to finish the case.

Dose, 10 H.

March 7.—The irradiated area began to get red three to seven days after exposure, and gradually assumed the tint of wine-lees, which it has at the present time.

For the last four days there has been a sanguinolent discharge from the left nostril when the patient blows his nose. There is some pain on the irradiated spot. The centre is slightly ulcerated. It should be noted that this reaction was purposely set up.

May 3.—Objectively the cure is complete. The cicatrix is hardly visible.

The patient was shown to the Société de Dermatologie.

Case XII.—M. G. L., aged sixty, gardener. Epithelioma of the left side of the neck of five or six years' duration. The disease commenced by a small pimple, and progressed slowly.

He has been treated for the last year or two with ointments and cauterization without any effect. He complains of pain and itching.

The lesion is oval, 5 centimetres long by 2½ centimetres broad.

The base is hollow, ulcerated, discharging, with no attempt at healing. It is surrounded by a hard raised edge, which is not ulcerated.

December 28, 1903.—Rays No. 6; séance of fifteen minutes; distance 20 centimetres; dose, 2 H. or 3 H.

December 29.—Second séance of fifteen minutes under the same conditions; dose, 2 H. or 3 H.

January 12, 1904.—The itching has diminished, and the base of the ulcer looks more healthy. The raised edge is flattened.

Dose, 2 H. to 3 H.; rays, No. 6.

January 13.—Dose, 2 H. to 3 H.; rays, No. 6.

January 28.—There is slight reaction. The pain is greatly diminished, but the tumour has not sensibly altered since the last visit.

Dose, 3 H.; rays, No. 6.

February 12.—The growth is decreasing; it is much flatter, and is now only the size of a sixpence. The edges are less prominent; the surface of the original lesion is covered by a dry crust. There is a slight discharge during the night, but no pain or itching.

Dose, 4 H. to 5 H.

February 13.—Dose, 2 H. to 3 H.

March 3.—The case looks better, and there is no discharge. There is a slight itching due to the reaction.

Dose, 2 H. to 3 H.

March 4.—Dose, 4 H. to 5 H.

March 28.—The lesion is quite flat, and does not project beyond the skin. Nothing remains of the original ulcer except a crust in the centre, which is hardly visible.

The induration is diminished. There is no adherence to the deeper structures. A slight amount of redness remains.

Dose, 4 H. to 5 H.

April 28.—The lesion is no longer visible, and is cured so far as objective symptoms go. A slight cicatricial depression marks the site of the original ulcer. There is no induration or tension of the skin, which is quite normal.

The total duration of treatment was four months. The irradiation was not very intense in consequence of the distance of the focus-tube. The reaction was in no instance excessive.

A total dose of 34 H. to 40 H. was given.

Case XIII.—Mme. D., aged sixty. Epithelioma perlé of five or six months' duration. It began by a small pimple the size of a bead below the right eye, 1 centimetre from the base of the lower lid, and 2 centimetres from the dorsum of the nose. This grew rapidly, till it has now attained the size of a pea.

November 25, 1903.—Electrical constants, 16 volts and 4 ampères; rays, Nos. 4 to 5.

November 26.—There was a certain amount of pain and smarting after yesterday's séance.

Dose, 3 H.

December 10.—Slight reaction; the pearl-like growth is somewhat flattened.

Dose, 6 H.

December 11.—Dose, 3 H.

The patient was not seen again till March.

March 4.—The epithelioma is reduced to three-fourths of its original size.

The remainder is removed by the curette, and the radiotherapeutic treatment is resumed.

March 17.—The ulceration following the scraping is irradiated.

Dose, 4 H. to 5 H.

March 18.—Second exposure.

Dose, 5 H.

Both of these exposures were given with the apparatus driven by a static machine.

April 25.—The case was examined by *Dr. Brocq*, who considers the patient cured. The scar is healthy, and hardly visible. In the centre is a small white spot, which shows the position of the pearl-like growth.

May 7.—A final irradiation is given to prevent recurrence.

The case was shown to the Société de Dermatologie.

Case XIV.—Mme. B., aged fifty-seven. Epithelioma of the dorsum of the nose. The centre is black, and covered with thin crusts. Around the circumference are pearl-like excrescences on an indurated base.

February 17, 1904.—Dose, 10 H; rays, No. 5.

March 10.—Slight reaction at the circumference. A crust remains at the centre. The whole is more supple, and the growth at the edges is regressive.

Dose, 3 H.

March 30.—The general appearance is excellent. No trace of the lesion remains, but only a slight redness. A dose of 3 H. is given to guard against recurrence.

Case XV.—Mme. P., aged sixty-five. Epithelioma of the eyelids on the left side. The patient was sent us by *Dr. Abadie.* Covering the inner third of the lower lid was an ulcerated surface of the size of a sixpence. The upper lid presented on its inner surface an epithelial growth, projecting beyond the margin, and not ulcerated. The eyelids had retained their power of movement. The disease began three years ago.

April 18.—Dose, 6 H; rays, No. 5. The eye is protected as much as possible.

May 3.—The growth on the upper lid is diminished. On the other hand, the ulcer on the lower lid is deeper and larger. The edges are more red and swollen, and the border of the ulcer is of a violet tint.

May 6.—*Dr. Sulzer* examined the patient, and thought that the inflammation of the eyelids was of an infectious nature. He recommends a continuation of the treatment.

Dose, 6 H.

May 27.—The ulceration has completely disappeared. The eyelid is not retracted, and the position of the original lesion can only be made out by a slight alteration in colour. The papule remains, but diminished to one-half of its former extent. *Dr. Abadie*, who saw the patient again, is astonished at the change.

Dose, 7 H. to 8 H. on the papule.

The patient is still under treatment. The result so far is very satisfactory.

At the present time the patient is almost cured.

Case XVI.—Marie B., aged thirty-seven. The case was sent to us by *Dr. Castel.* Cutaneous epithelioma, commencing eleven years ago. The lesion, which is situated on the margin of the ala of the nose, has been treated by different procedures.

At the present time the lesion is covered with a crust, with pearl-like excrescences on the nose. The naso-genian groove is affected.

March 9 and 10.—Dose, 9 H. in two séances; rays, No. 5.

March 28.—The reaction is marked, and there has been some epistaxis.

April 14.—The reaction has abated. An irradiation is given to the lesion in the naso-genian groove.

Dose, 6 H. in two séances.

May 2.—The naso-genian groove is red. On the end of the nose there is a seborrhœic crust, which has fallen off here and there, leaving underneath it a red cicatricial skin, from which the pearl-like excrescences have disappeared.

Dose, 5 H.

May 16.—Sharp reaction, which is passing off.

June 1.—The nose is much better, and may be considered cured. There is still a suspicious point on the naso-genian groove.

Dose, 5 H.

The patient is still under treatment, but the case may be considered cured.

Case XVII.—M. J., aged seventy-five. Small epithelioma on the right ala nasi of six years' duration. Treated in December last by the actual cautery.

At the present time there is ulceration and incrustation. The edges of the ulcer are indurated, and a few epithelial pearls are to be seen. There is no infiltration. The patient complains of itching.

From February 17 to May 20 the patient had six irradiations, with doses of 8 H., 8 H., 6 H., 8 H., 10 H., and 5 H. respectively.

The ulceration has noticeably diminished, and healing is progressing. The case was a very obstinate one, and we were therefore obliged to raise the dose to 10 H.

The patient is completely cured; the wound has healed without retraction. The appearance of the scar is most excellent.

Case XVIII.—M. L., aged eighty-one. Epithelioma of the left ala of the nose, which is ulcerated and covered with a crust.

April 18.—Dose, 8 H.; rays, No. 5. The case is still under treatment, but the improvement is undeniable.

Case XIX.—Mme. P. B., aged sixty-seven. Epithelioma of the forehead. The disease began three or years ago, and progressed gradually. An operation was performed in November, 1903, and the whole was scraped down to the periosteum. There was a return at the end of six weeks.

At the present time the lesion presents a curious appearance. There are two hemispherical growths about 8 millimetres in diameter and of the same height, on an indurated base the size of a five-shilling piece. The papular

growths are crateriform, with hardened edges covered with whitened crusts, which bleed easily. The whole lesion is hard and adherent to the deeper structures. The patient complains of great pain.

The crusts were removed by scraping, and an irradiation followed.

February 20 *and* 23.—Total dose, 10 H. ; rays, No. 5.

March 4.—The lesion is less raised. The pain has been severe. The reaction is only slightly marked. The ulcerated surfaces do not bleed so easily.

Dose, 7 H. ; rays, No. 5.

March 30.—The improvement continues. The crateriform growths have disappeared almost entirely. There is a certain amount of peripheral redness, with ulceration in the centre.

April 18.—The lesion is almost flat, with a star-shaped cicatrix in the centre. On the right is a small ulceration.

Dose, 6 H. ; rays, No. 5.

May 8.—Reaction and redness. Slight ulceration exists on the right side. There is no trace of tumour or infiltration. The patient may be considered cured, but is to return to us when the inflammation has abated.

June 10.—The patient is completely cured.

Case XX.—Mme. P., aged fifty. Epithelioma larvé of the left temporal region of a year's duration.

There is an erythematous patch of the size of a sixpence, with hard borders, raised and squamous. This is covered with nodules. The whole is slightly infiltrated, but non-adherent to the deeper structures.

From February 29 to May 26 the patient had four applications, with doses of 8 H., 5 H., 4 H., and 3 H. respectively.

On May 26 the case was apparently cured. A last seance was given to guard against recurrence.

Case XXI.—Mme. P., aged forty. Superficial epithelioma of the dorsum of the nose. The lesion is of four years' duration. It presents a cicatricial aspect, with induration and pearl-like excrescences. It has been treated for four years by different methods.

March 26.—Dose, 6 H. ; rays, No. 5.

April 15.—Dose, 9 H.

May 11.—Sharp reaction. Ulceration, with a reddish violet margin. The centre seems inclined to slough. The ulcer is treated with oxide of zinc paste.

May 25.—The patient returned with a great improvement of the nose. Cicatrization is complete. There is no trace of the lesion, and the general appearance is most excellent.

Dr. Brocq, who saw the patient, was surprised at the rapidity with which the ulcer healed. It is noticeable what a small dose of rays, 15 H. in all, was sufficient to produce a cure.

Case XXII.—M. P., aged seventy-nine. Epithelioma of the lower part of the dorsum of the nose, first appearing some seven months ago.

The patient has an ulceration 1 centimetre in diameter, and about 1½ centimetres deep. It is anfractuous, with a sero-purulent magma at the base. The margin is raised with an indurated base, comprising the whole of the extremity of the nose. If the ala of the nose is pressed there is an exudation of sero-pus from the large crateriform opening.

Similar lesions in earlier stages occur on other parts of the face.

April 30.—An irradiation of 9 H. with No. 5 rays.

May 11.—The ulceration is slightly improved; the peripheral swelling is flatter. The reaction is fairly acute. An irradiation is given to an epitheliomatous lesion on the left cheek-bone, which was covered with crusts and ulcerated; dose, 10 H.

May 30.—The crusts on the cheek have fallen off. There is a well-marked erythema. The nose is much better; it is still red, but the crater has diminished in size by about two-thirds. The opening is 5 to 6 millimetres in diameter, but it is still fairly deep. Suppuration, which was very pronounced after the last irradiation, has given place to a slight oozing. The general appearance of the lesion is improved.

Dose given, 6 H.

The patient is still under treatment, and not yet entirely cured. It is curious to note the rapidity with which the reparation has been effected. The case was inoperable, as an operation would have involved the removal of the whole of the end of the nose.

The patient was seen again on June 24, when nothing was visible but a slight erosion of the tip of the nose, which was healing. When seen again in October, the patient was completely cured.

Case XXIII. — M. T., aged seventy-six. Ulcerated epithelioma of the nose.

The disease first appeared in October, 1902, since when cauterization has been resorted to five times without success.

January 14, 1904.—A dose of 11 H. was given in two consecutive séances with No. 5 rays. From this date to April 12 four further irradiations were given, the doses being respectively 7 H., 5 H., 5 H., and 4 H.

At the latter date the crusts had all fallen off, and the ulceration was reduced to a single oozing spot.

The patient has not since been seen.

Case XXIV.—M. D. The patient suffered from an epithelioma, developing from a seborrhœa, and had previously been treated by curetting. On admission the lower two-thirds of the nose was covered by a concrete seborrhœa, which extended into the ducts of the sebaceous glands.

There was commencing proliferation on the cicatrix caused by the operation on the tip of the nose.

August 26, 1903.—Twenty-five minutes' irradiation at 15 centimetres distance; equivalent spark, 2½ centimetres; penetration of rays, No. 5; quantity, 4 H. on every part of the nose.

August 27.—A similar irradiation of the same region.

October 15.—No amelioration visible. The patient came very irregularly. Twenty minutes' irradiation; quantity, 3½ H. to 4 H.

October 16.—A séance of fifteen minutes' duration under the same conditions as on the preceding occasion.

November 2.—The nose is considerably improved, and the seborrhœa diminished ; a few epithelial nodules remain on the tip of the nose.

Séance of twenty minutes ; quantity, 4 H.

November 13.—There is still a good deal of seborrhœa. Some small whitish nodules have appeared at the root of the nose. Séance of twenty-five minutes ; quantity, 4½ H.

November 14.—Another séance of forty minutes; quantity, from 3 H. to 4 H.

November 27.—The nose is slightly red ; a crust has appeared at the tip; the nodules at the root of the nose persist. These are irradiated, the rest of the nose being carefully protected.

Séance of fifteen minutes ; quantity, 4 H.

December 4.—The redness has diminished; seborrhœic filaments may still be drawn out of the sebaceous ducts; the crust on the tip of the nose has almost disappeared. The nodules are less, and are beginning to disappear. The patient complains of itching.

As only ten days have elapsed since the last irradiation, a single séance of fifteen minutes is given, and this is confined to the nodules still in course of evolution ; dose, 4 H.

December 30.—The itching continues ; there is slight desquamation of the nose. No signs of erythema. Séance of fifteen minutes ; quantity, 2 H. to 3 H.

January 11, 1904.—The nose is covered with adherent oleaginous scabs. Their number is probably increased by the influence of the weather. The crust on the tip of the nose has re-formed, and is larger and of a yellowish hue. No itching or pronounced redness.

An irradiation of fifteen minutes over the whole surface of the nose ; dose, 3 H.

January 27.—The crust has fallen off, leaving in its place a clean cicatrix ; the seborrhœa is much reduced, although the glandular orifices are very dilated. *Dr. Brocq* on seeing the patient considers the cure complete.

February.—There is no active lesion, but some signs of seborrhœa remain.

March.—The parts formerly diseased have remained healthy. The general appearance is excellent; there is still some seborrhœa, but it is very much reduced. The patient was shown to the Société de Dermatologie.

Cancer of the Breast.

No one can read the current literature on radiology without being struck by the large number of papers dealing with the treatment of cancer of the breast by the X-rays.

Almost every author interested in radiotherapy has published more or less favourable results. It is difficult to form a just opinion as to its merits. Some authors claim to have obtained complete cures, others report amelioration, whilst still others have seen no improvement from the use of X-rays.

A cause of this divergence of opinion is probably to be sought

in differences of technique, but chiefly in the diversity of forms assumed by this disease, both in its appearance and in its evolution. Setting aside American reports, which are too numerous to enumerate here, we may mention among European authorities *Vigouroux*, *Mondain*, *Biraud*, *Mikulicz*, *Schiff*, *Reboul*, *Perthes*, *Béclère*, and *Haret*.

We will not repeat the tedious details of all these cases.

A cancer of the breast may be primary—one that has not undergone any surgical interference—or it may be a recurrence after operation.

We will therefore divide this section into two parts: cancer of the breast properly so-called, and recurrent cancer after operation.

Primary Cancer of the Breast.—The efficacy of radiotherapeutic treatment in cancer of the breast has been vigorously denied by a large section of the medical profession.

In spite of successful cases reported by such conscientious observers as *Skinner*, *Morton*, *Williams*, *Stelwagen*, *Schiff*, *Mondain*, and others, one is forced to doubt the reality of these cures.

Thus in 1903 *Labbé*, while admitting the therapeutic effects of X-rays on the cancerous ulceration, maintained that as yet there is no proof of the absolute cure of the cancer.

At the Congrès de Chirurgie, *Professor Tuffier* asserted that no true deep-seated cancer was benefited by radiotherapy. Quite recently *Professor Poirier* denied the efficacy of this method, and condemned it as dangerous, since it delayed operation and thus gave the neoplasm more time to develop.

These somewhat severe criticisms are due to several causes. Firstly, the number of neoplasms of the breast cured by irradiation is small when compared with the number of cases treated. The small number of successes is in great measure due to the fact that most of the cases treated are inoperable cancers of great severity and wide extent, in which radiotherapy has been turned to as a last resource when all else has failed.

Further, we must realize that the application of the treatment presents a very real difficulty. The mode of treatment, the succession of exposures, the dose, the degree of reaction which must be attained but not exceeded—all these demand of the operator a deep insight into the theory of the methods, a perfect control of his apparatus, and a rigorous measurement of the quantity of rays absorbed.

Unfortunately, as with all new methods of procedure, radiotherapy has frequently fallen into the hands of unscrupulous operators, who pretend to supply that which they are incapable of correctly estimating. They thus throw unmerited discredit on the new treatment, and in part justify the criticism to which it has been subjected.

This abuse of the new treatment is not confined to France; it is to be found in all countries. We read in *Skinner's* interesting report: 'Certain medical men of great repute have adopted X-rays as a therapeutic agent, but instead of becoming themselves proficient in their use, or of employing an experienced specialist, they confide the application of the rays to a nurse or to a radiographist, who may not know anything about radiotherapy. When they publish the clinical results obtained under these unsuitable conditions, their name gives to these reports a weight far in excess of their intrinsic value, and this has introduced an element of confusion into the problem.'

Finally, the results themselves were so surprising that it seemed impossible to suggest any possible explanation, and one was led to doubt their authenticity. It appeared incomprehensible that lesions so malignant should be cured by an invisible therapeutic agent acting from a distance, whose action was not marked by any sensation during the time of treatment.

There was here an element of mystery, which seemed incompatible with all our accepted ideas.

In order to estimate the therapeutic value of X-rays in the treatment of cancer of the breast, we require experience lasting over a considerable time, and well authenticated statistics for many years. The method is as yet too recent to allow of authoritative decision. Nevertheless, it is possible to indicate the time of treatment which seems best, and to do this we must first distinguish the different affections classed under the term cancer of the breast.

Most of the women who come to the radiotherapeutic specialist with cancer of the breast are affected with the disease in an advanced stage. The breast is hard and voluminous, the nipple is retracted, and the skin resembles the rind of an orange. The tumour is adherent to the deeper layers, and the muscular tissues are invaded. The glands of the axilla and of the subclavicular region are enlarged. The arm on the affected side is painful and useless. It is usually hard, œdematous, and abnormally vascular.

The breast also is the seat of intense pain. The patient is emaciated and cachectic, and complains of difficulty of breathing and dyspnœa.

Radioscopic examination reveals the presence of deep-seated glands. The general system is infected, the course of the disease is rapid, and the case is declared inoperable.

In such a case radiotherapeutic treatment cannot determine the regression of the neoplasm. It can only act as a palliative measure. As a rule, it will alleviate the pain, and thus allow the unfortunate patient to end her life in comparative comfort.

Occasionally, however, the sedative action of the rays fails. In two cases of cancer of the breast—one widely ulcerated, the other one in which the skin was almost intact—irradiation was followed by a recrudescence of pain. In one of these cases the pain might possibly be due to neuralgia of an intermittent character. Observation showed, however, that besides the neuralgia there was an increase of pain in the tumour itself.

It is difficult to decide if this was a simple coincidence or an instance of cause and effect.

In the second case there was a large ulcerated surface adherent to the deeper tissues, where mere exposure to the air might account for the increase of pain.

Although these exceptional cases should be noted, the observation does not in any way diminish the value of radiotherapeutic treatment. The analgesic action of the rays is indisputable, and in all our cases it was the first, if not the principal, effect of treatment.

'Often,' says *Skinner*, 'the pain of cancer is ameliorated by the X-rays. This degree of improvement varies from a slight diminution to complete disappearance of the painful symptoms. This is the only treatment which enables us to dispense with the use of morphia.'

Besides its sedative action, the effect on the morale of the patient must be taken into consideration.

Consider the case of these unhappy women, who have tried every means of treatment in vain, and see themselves abandoned to their fate.

They have heard of the X-rays, and come full of hope to consult a specialist. Without promising a cure, we may lead them to hope for some relief and a cessation of their pain. In inoperable cases the treatment can, at any rate, do no harm.

In certain cases, especially in the early stage, the X-rays have a marked effect.

Skinner has seen severe and malignant lesions of large extent cured by the X-rays.

Without being too optimistic, one may assert that in many cases the health is improved and the tumour diminished in size. In this way life is often prolonged, since, as *Kienböck* says, radiotherapy certainly retards the evolution of the disease. *Williams* is of opinion that the first effect of the X-rays is to arrest the production of toxic materials, which are absorbed from the lesion and thus introduced into the circulation.

In spite of X-ray treatment, however, the cancer continues to grow, although more slowly than before, the lymphatic glands become infiltrated, and metastases occur.

There may be some diminution of the œdema, although ordinarily there is no great alteration in this respect.

The case is still operable as long as the disease is in an early stage and the tumour is small, with perhaps thickened and adherent skin, but with no infiltration of the glands, and but little cachexia.

In such a case radiotherapy should yield to surgery. There should be no delay, even to try what the X-rays will do. During the delay of some weeks necessary for this purpose the disease may progress, and surgical intervention be too late.

At the present day, however, the patient should not trust to surgical treatment alone. When allied with radiotherapy, it has a much greater chance of success. Radio-surgical treatment should be adopted—that is to say, every operation should be followed by a series of irradiations.

'Surgical treatment,' says *Léonard*, 'is not scientific. The Roentgen rays alone have a destructive action on the morbid tissues, and arrest the infection and cystic degeneration. We have not as yet obtained absolute confirmation of these results. Time is required, and until then we must still have recourse to ablation of the tumour, with subsequent radiotherapeutic treatment.

'One cannot sufficiently insist on this post-operative treatment by means of the Roentgen rays. It is the only means capable of destroying any microscopic foci of disease which may have been left behind after the operation.'

In America several authorities have advised the irradiation of the seat of operation before the closure of the wound. This pro-

cedure has much to recommend it, and it is to be hoped that it will become habitual. When this is done, the rays do not suffer diminution by the absorption of the skin, and the deeper foci may be acted on more intensely without danger of dermatitis.

It may be advisable to commence a series of irradiations before the complete cicatrization of the wound. This may be done through the dressing, so as to avoid all danger of infection. The dose should be a slight one.

In other cases it will be enough to commence radiotherapeutic treatment after cicatrization is complete. The irradiations should extend over the whole of the operated region, and especially over the line of the cicatrix. The axilla and the subclavicular region should also be irradiated.

The permanence of the cure will depend on the state of the thorax at the time of operation. If the pleura and mediastinum are unaffected one may hope for a successful issue. If operation has been too long deferred, there may be no recurrence on the surface, but the patient will probably succumb to the more deeply-situated neoplasm, on which the X-rays appear to have but little influence.

In the case of small tumours, with slow growth and little or no enlargement of the axillary glands, one may hope to obtain arrest of evolution and regression of the tumour.

We have treated several patients who have refused operation, and have seen a marked diminution of the size of the tumour after a few exposures. The glands have disappeared and the general health has been improved.

We have not, however, been able to procure the complete absorption of the neoplasm. At a certain moment the regression is arrested and the tumour seems to become insensible to the action of the rays. It remains stationary, giving one the impression of an encapsuled fibroma.

On the other hand, several cases, apparently similiar in character, were not in any way modified. Even in these cases, however, it was rare for the lesion to increase or the cachexia to progress. Even when the treatment was unable to alter the neoplasm, it seemed to arrest its evolution.

The lesions which are most obstinate to radiotherapeutic treatment are the hard, painless scirrhous cancers of the breast, which have taken as much as five or six years to attain the size of an orange. On these the X-rays have apparently no influence whatever.

American authors assert that the more rapidly the disease is extending, the more easily is it affected by the X-rays. We do not consider this to be the case. In our experience the lesions which have been most readily influenced are those which have a slow course of evolution.

It may be questioned whether there is a difference in histological structure between malignant tumours which react on the X-rays and those which are not affected. Hitherto the microscope has revealed no difference in this respect.

In spite of the favourable results of radiotherapy alone, there is no doubt that the best mode of treatment is by means of an operation followed by irradiation. If the patient absolutely refuses operation, radiotherapeutic treatment should be tried; but this rarely results in a complete cure.

In cases where the cancer of the breast is ulcerated, and accompanied by enlarged glands and extension to the deeper tissues, an operation should still be performed where possible. In such cases radio-chirurgical treatment should be adopted. Radiotherapy alone will yield no definite result, although it may lessen the discharge, allay the pain, and diminish the ulceration.

If the ulceration is superficial, without much enlargement of the glands or induration of the breast, and if the edge of the ulcer is not raised and hard, the X-rays may give good results.

These lesions, which are generally considered the severest forms of cancer, are, in our opinion, those which are most susceptible to cure by radiotherapy. They are usually confined to the integument, and are therefore very amenable to the action of the X-rays.

In these cases a strong dose may be given. Dermatitis is not to be feared, since there is no skin, and the action is more intense because the rays are not absorbed by the integuments.

After a few séances the wound changes is aspect, begins to granulate, and finally heals. *Schiff* reports a remarkable case of this sort. The prognosis depends principally on the state of the glands. It is well to irradiate these even where they are apparently unaffected.

The injection of adrenaline may be employed in conjunction with the Roentgen rays. In certain cases it may be necessary to use the knife or the thermo-cautery in order to reduce the thickened edge of the ulcer.

To resume: In primary cancer of the breast an operation should

be performed even in apparently benignant cases. Although the X-rays may be able in certain cases to continue the regression of the neoplasm, yet time is gained by surgical intervention, and the result is more permanent.

Technique of Treatment.—A course of irradiation should be commenced directly after operation.

At the commencement rays of medium penetration may be tried —Nos. 6 or 7 on Benoist's scale—so as to act more especially on the skin. Later on harder rays, Nos. 9 or 10, should be employed, in order to reach any deeper foci that may have been missed by the knife. The more penetrating rays will also act better on the contaminated glands.

If the cicatrix is a long one it may be necessary to make two contiguous irradiations.

At each application the dose will vary from 4 H. to 5 H., and a period of twelve or fourteen days should intervene between each irradiation.

All violent reaction is to be avoided, and the state of the skin will guide the operator as to the intensity and frequency of the irradiation.

The treatment may be continued for three or four months. If at the end of this time the cicatrix is healthy and the skin normal, and there is no sign of recurrence, the irradiations may be suspended. The patient should be watched, however, and the treatment recommenced on the first sign of recurrence.

The physician should be guided by the following rules:

'To cause the absorption by the tumour of the largest quantity of radiations compatible with the integrity of the skin.

'To separate the irradiations by as short an interval as possible, having due regard to the integrity of the integument.'

We usually employ rays of penetration Nos. 9 or 10. There are two modes of procedure of which we adopt one or the other according to the severity of the disease and the time at the patient's disposal.

The first method is to give a dose of 4 H. to 6 H. every week to each region. This method is reserved for severe and widespread lesions.

In the second method we give 6 H. or 7 H., and wait a fortnight before giving a second irradiation.

Sometimes the two methods are combined, beginning with irra-

diations once a week, till the state of the skin obliges us to lengthen the intervals.

In this way we can better watch the evolution of the inflammatory symptoms, and thus avoid radiodermatitis.

It should be remembered that radiotherapy is not a caustic treatment, as was once imagined.

The X-rays determine the recession of a neoplastic growth, not by setting up dermatitis, but by a special resolvent action on the cancer cells themselves.

Cutaneous reaction is useless and harmful, and radiotherapy will have made a great step in advance when it can be avoided with certainty. This is not easy, however, for in order to attack the deeper tissues, the rays must always traverse the integument.

In order that the tumour may receive a sufficient quantity of the rays, the skin must absorb as much or more. It will therefore react, in spite of all our precautions, but the reaction should never be allowed to pass beyond a moderate erythema.

In certain severe forms we are obliged to diminish the intervals between the séances, even at the risk of setting up radiodermatitis. This will be of small importance in comparison with the spread of the disease, although it has the disadvantage of obliging us to stop the treatment until the reaction has calmed down.

Some authorities advocate the employment of a thin shield of aluminium between the focus-tube and the patient. This acts as a sort of filter, stopping the more noxious rays, and allows a greater dose to be given with safety to the skin.

This procedure is not found to be of any great practical advantage.

On the contrary, when the X-rays traverse the aluminium screen, they give rise to secondary X-rays of feeble penetration, which may act on the skin and produce inflammatory phenomena. A sheet of black paper should therefore be interposed between the aluminium shield and the skin, so as to absorb these secondary X-rays.

In cases where the neoplasm is ulcerated the dose of the rays may be increased, since tissues which are bare of integument are less easily affected by the rays.

At the beginning of treatment we give a dose of 8 H. or 9 H., and repeat this every fortnight.

The ulcer should be treated with antiseptic dressings. Moist

applications appear to act best. The use of dense powders, such as iodoform, is to be avoided, as these arrest a portion of the rays.

In the treatment of large and thick tumours, *Professor Perthes* advises that the focus-tube should be placed at some considerable distance from the skin, so that the quantity of rays absorbed by the tumour may not differ greatly from that absorbed by the skin.

Supposing the anticathode to be placed 4 inches from a tumour of the breast which is 2 inches in thickness. Let us further suppose that midway between the anticathode and the skin the quantity of rays in a unit of time may be represented by 9. In the same time the quantity which strikes the skin will be one-fourth of this, since the amount diminishes with the square of the distance.

$$\frac{9}{2 \times 2} = \frac{9}{4} = 2{\cdot}47.$$

At the greatest depth of the tumour—that is, at 6 inches from the focus—the quantity of rays will be represented by

$$\frac{9}{3 \times 3} = \frac{9}{9} = 1.$$

Thus while the skin is receiving 2·25 units of quantity, the tumour in its deepest part will only receive 1 unit. This is on the supposition that the tumour is of the same density as air. In practice the difference would be even greater.

If, on the other hand, we suppose that the focus-tube is placed at a distance of 40 inches, and the skin receives 1 unit of X-rays in a given time, an object placed 2 inches from the anticathode will receive 400 units.

$$1 \times 20^2 = 1 \times 400 = 400.$$

Similarly, a point on the deeper surface of the tumour will receive a quantity

$$\frac{400}{21^2} = \frac{400}{441} = 0{\cdot}909.$$

That is, when the skin is absorbing 1 unit, a point 2 inches below the surface is receiving 0·909 unit, on the supposition that the tumour is of the same density as the air.

In this case the quantities absorbed by the different layers of the tumour are almost equal.

Thus the further the tube is placed from the tumour, the less will be the difference between the quantity of rays absorbed by different layers of the tumour.

The greater the distance of the tube, the greater the length of exposure. This consideration limits the distance, which is useful in practice.

In conclusion, we may allude to the sensitization of the tissues by the injection of a solution of the acid hydrochloride of quinine. Although some experiments were made by *Dr. Béclère*, this method has not been tried long enough for us to give any positive opinion as to its value.

Cutaneous Recurrence after Operation.—It is in recurrence after operation that radiotherapy produces the most successful results. In this respect it is better than surgical intervention, and its success leads us to hope that it will act in like manner on deeper lesions when the technique of the method has been brought to perfection.

On this question authorities are particularly unanimous. We quote *Reboul* of Nîmes, who is a surgeon, and one of the most recent writers on the subject. He says: 'The Roentgen rays have a most favourable action in cases of cutaneous recurrence after operation for cancer of the breast. Under their influence the pain is alleviated, the cutaneous tumours are absorbed, and the induration and œdema disappear. The rays act locally, and not on the general cancerous infection.'

The success of this local action depends in great measure on the state of the lesion and the extent of the neoplastic growth.

The less the glands and the deeper structures are involved, the greater is the chance of cure.

There are two varieties of post-operatory recurrence. In the first the disease involves only the skin and superficial tissues, either because the disease is in an early stage of its evolution, or because it is only able to invade the integument.

In the second variety the deeper structures are involved. The tumour is adherent to the muscles and bony structures, and the glands are affected. The enlarged glands may be felt in the axilla and subclavicular region. A radioscopic examination may show that the pleura is attacked, or that there is hypertrophy of the medi-

astinal glands. In this variety the disease has already become generalized.

In the first variety radiotherapy will produce absorption of the foci of disease, and this without erosion, ulceration, or sloughing.

Small button-like nodules which are sometimes seen in recurring cancer yield readily to a few exposures. A dose of 5 H. or 6 H. should be given every ten or fifteen days, with rays of penetration Nos. 8 or 9. It is advisable also to irradiate the glands.

The results are also very favourable when the disease recurs in the shape of small, hard subcutaneous nodules, which are freely movable. A dose of 4 H. or 5 H. may be given every week or ten days, increasing the intervals after a time so as to avoid dermatitis. In this way we have obtained the complete regression of several cases of cutaneous recurrence.

The condition is less favourable when there is a seed-like infiltration of the integument, which is hardly visible, but which may be felt by passing the hand over the surface. These cases may be ameliorated, but while one spot is being treated the lesion is apt to progress elsewhere, and to become generalized.

The results of X-ray treatment are more favourable when the recurrence affects the cicatrix of the wound or sutures.

Ulceration, accompanied by nodules recurring after an operation, is improved in a surprising manner.

These ulcers, of evil aspect, with sanious base and fœtid odour, improve rapidly. At first the secretion is increased, but this soon diminishes, and finally ceases. The odour disappears, the ulcer improves in appearance, and cicatrization follows, while at the same time the cutaneous nodules are absorbed.

In these cases we usually prescribe moist applications to remove the crusts, and to diminish the chance of infection of the wound from without.

The ulcer and surrounding region is irradiated, with a dose of 5 H., using rays of medium penetration. We then place over the region a shield of lead with apertures corresponding to the ulcerated points, including a margin ½ centimetre in width.

After this a further irradiation of 2 H. or 3 H. is given, so that the ulcerated surface receives a dose of 7 H. to 8 H., while the skin has only absorbed 5 H.

The séances may be repeated every ten or fifteen days, according to the state of the skin.

When the lesion is not adherent to the deeper tissues, but the glands are enlarged, we may often observe a curious phenomenon of regression. This was the condition in a case which we saw with *Dr. Bisserié.* The patient had been operated on for cancer of the breast some eighteen months previously. The disease recurred so frequently that the patient had already undergone eight operations during a period of fifteen months. When we first saw her, she had a number of cancerous nodules of the skin. Some of these were of considerable extent, and formed quite large patches. The pain was intense, and the cicatrices were unhealthy. There was an enlarged gland in the clavicular region.

In the axilla there were three enlarged glands, two superficial and one more deeply placed. According to custom, the irradiations were directed on the mammary region. A strong dose of 9 H. was employed, as the disease was progressing rapidly. After three or four exposures the pain ceased entirely. The supraclavicular gland and the two superficial glands in the axilla disappeared completely. The cutaneous nodules became flatter, and also disappeared. The cicatrix became softer, and the patient discontinued treatment, as she considered herself cured. Since that date, 1903, there has been no cutaneous recurrence, but she complains of dyspnœa, which makes one fear there may be a recurrence in the deeper structures.

Biraud also reports a case in which some enlarged supraclavicular glands disappeared at the same time as the cutaneous lesion.

In a case of enlargement of the axillary glands we have seen a great diminution follow the direct irradiation of the glands. If we compare the surgical and the radiotherapeutic treatment of the case reported above, we must allow that the former was followed by recurrence after a short interval, whereas the latter resulted in a complete cure.

After a few irradiations the cutaneous nodules of recurring cancer seem veritably to dissolve away. Failure is, however, only too common, and sometimes we may see a new outbreak beyond the limits of the irradiated region. In this case the physician may think himself fortunate if he is able to arrest the evolution of the disease.

The results of treatment are not so satisfactory in cases where the recurrence is more advanced, when the lesion is adherent, or when the glands are involved.

Radiotherapeutic treatment can then be regarded only as palliative. It may calm the pain and diminish the size of the tumours, but it will not arrest the disease or prevent the final cachexia. In these cases a dose of 4 H. to 5 H. may be given every week or ten days.

When the growth is voluminous, it may be advantageous to precede the radiotherapeutic treatment by a surgical operation, which in any case can be only palliative, and will not long delay the fatal termination.

Deep-seated Cancer—Cancer of the Abdominal Organs.

Cases have been published of cancers of internal organs—stomach, intestines, uterus, etc.—cured by the X-rays.

These reports have been received with a good deal of scepticism. Personally we are not in a position to give an opinion. In our own practice we have met with no signs of success, but this may possibly be due to a faulty technique.

Skinner, in his report on the subject, speaks thus: 'In cases of intra-abdominal cancer the percentage of favourable results by any other means is so small that we should have recourse to extirpation whenever that is possible. The operation should invariably be followed by a long series of irradiations. It is difficult to estimate the value of the combined method, as the cases hitherto treated by the X-rays are usually inoperable. The fact that a few cases have been cured under these disadvantageous conditions leads us to hope that in cases which are operated on in an early stage the consecutive action of the X-rays may be able to arrest the progress of this terrible disease.

'Opinions are unanimous as to the value of the X-rays in cancer after operation and in inoperable cases. The pain is alleviated, the general health improved, and existence is prolonged.'

In an interesting review by *Delherm* and *Laquerrière*, the authors state: 'The favourable results obtained in a few exceptional cases prevent us from totally rejecting radiotherapy. Failure, however, is so frequent, and the results of our own experience are so dis-

couraging, that we have no great hope for the future of the treatment.'

Two French authors, *Doumer* and *Lemoine*, have for some time past treated tumours of the stomach by radiotherapy. We reproduce a part of their communication to the Academy of Medicine:

'We have treated twenty cases of tumour of the stomach with the X-rays. Of this number three have been completely and permanently cured, a fourth case is improving, and a fifth has recurred after the complete disappearance of the tumour. The other cases have followed the usual course—the patients have succumbed, and it is impossible to say if their life had been prolonged by the treatment or not.

'In all cases it has alleviated the pain partially or entirely, and this after only one or two applications. The vomiting has ceased or been greatly diminished, thus rendering alimentation more easy. There has thus been a considerable amelioration of the general health and of the local condition.

'The tumour of the stomach has in all cases diminished, and in certain instances it has completely disappeared. Unfortunately, it always has reappeared either in the vicinity of the original growth or in some neighbouring organ—the liver, pancreas, epiploön, or lung. The treatment seemed only to affect the tumours which were more superficial in position. After a brief period of remission, due to the X-rays, a generalization of the disease occurred, and the patient succumbed.

'Radiotherapy therefore is able to influence one variety of tumour of the stomach. In certain cases it has produced a complete cure, which has been maintained after an interval of eighteen months. In other forms it acts incompletely, destroying the original tumour without preventing its extension to neighbouring tissues.'

What *Doumer* and *Lemoine* have done for cancer of the stomach, other authors have attempted for cancer of the uterus.

Suilly reports three successful cures of cancer of the neck of the uterus. He says: 'In early stages of cancer of the neck of the uterus complete ablation of the organ should be attempted. In later stages, however, when the vaginal cavity and the body of the uterus are invaded, treatment by X-rays should be adopted.'

In conjunction with our colleague *Dr. Mézerette*, we have treated some cases of cancer of the neck of the uterus with a certain

amount of success. The pain has been alleviated, and the hæmorrhage lessened. The rays were directed on to the tumour, *per vaginam*, by means of a Ferguson's speculum. It is impossible to speak with certainty of the results, as the patients are still under treatment.

Analogous results have been obtained in cases of cancer of the rectum.

It may be doubted whether the diagnosis is always correct in cases said to be cured by the X-rays. Nothing is more difficult than to determine the nature of an abdominal tumour. Were the tumours of the stomach cured by radiotherapy always veritable neoplasms? May not a hypertrophy of the liver have been mistaken for a tumour of the pancreas or pylorus?

It is possible that some deep-seated tumours may be influenced by the X-rays. These act on cutaneous cancer, sarcoma, and cancer of the breast. Why should they not have a similar effect on tumours within the abdominal cavity?

An abdominal tumour has usually attained a considerable size before it is detected; the disease has generally invaded the neighbouring organs and the lymphatic glands. Most of the cases submitted to treatment are inoperable, and in a hopeless condition.

Moreover, the situation of these tumours is very unfavourable for radiotherapeutic treatment.

In order to reach a cancer of the uterus or the liver, the rays must traverse the skin and the muscles, and the other tissues covering the organ.

They will be diminished in intensity before reaching the tumour. The quantity absorbed will be small, and this must penetrate the whole of the tumour.

We may obviate some of these disadvantages by a prolonged exposure, or by increasing the penetration of the rays, but this is limited by the sensitiveness of the skin and mucous membrane.

It is difficult to avoid dermatitis, since a considerable quantity of rays reaching the tumour presupposes a greater quantity absorbed by the skin. The dose given to a deep-seated tumour must always be limited to a quantity less than that required to set up reaction of the skin.

Even if we admit that the X-rays in sufficient quantity are able to determine the regression of deep-seated neoplasm, the problem is still a difficult one.

If there were any satisfactory means of isolating them, one might use only the more penetrating rays. It is well known that the focus-tube emits a number of rays of different degrees of penetration, and the harder rays are always accompanied by a number of softer and more noxious radiations.

The aluminium screen may render some service by filtering out the softer rays, but it diminishes the harder rays as well, and it has not proved to be of much utility in practice.

It has been proposed to introduce some radio-active substance into the neighbourhood of the tumour by means of a sound. The difficulties of this procedure are obvious, and there is also the danger of producing ulceration at the point of contact.

It has also been suggested that a portion of skin might be removed, so as to form a sort of window for the entry of the rays. This procedure would have manifest disadvantages, and would not obviate the absorption of the rays by the deeper tissues.

The tumours most susceptible to the action of the rays are therefore those of small extent and of slow growth, at no great distance from the surface.

Thus, cases of intestinal cancer appear to be most amenable, while cancer of the pancreas, kidney, and stomach are least so.

There are two principal objects to be kept before us in treatment—the absorption of the maximum dose of rays by the tumour and the avoidance of all violent reaction of the skin.

In order to attain this, rays of considerable penetration, Nos. 10 to 12, should be employed. The surface of the skin should be screened by a sheet of aluminium one-fifth of a millimetre in thickness. The tube should be placed from 12 to 16 inches from the skin, and a dose of 6 H. to 7 H. should be given once a week, with a gradual diminution of the dose and increase of the intervals in order to avoid dermatitis.

By placing the focus-tube at some distance, it is possible to give a comparatively large dose to the neoplasm without injury to the skin.

In some cases, as in cancer of the œsophagus, we may irradiate the anterior surface and the two sides in succession. In this way the tumour absorbs a dose of 15 H., while each area of the skin receives only 5 H.

In the same manner, disease of the stomach and mediastinum may be attacked from all sides.

The foregoing remarks apply only to inoperable cases. We cannot too often repeat that *whenever an operation is possible, it should be performed before radiotherapeutic treatment is attempted.* It would be a grave error to delay an operation in the case of a deep-seated cancer which could be removed with any chance of success.

Surgical intervention should be followed by irradiation with the smallest possible delay. Perhaps in the future the alliance of the two methods may give us more permanent results, and a recurrent cancer may become a rarity.

When the case is inoperable, or if an operation is refused, radiotherapy will still prove a palliative whose utility cannot be overestimated.

The Supposed Dangers of the Radiotherapeutic Treatment of Cancer.

From the first the accidental occurrence of toxæmia or metastasis has been reported in cases of cancer treated by the X-rays.

Naturally, it was concluded that the rays were the cause of these accidents, and the treatment was not so harmless as was at first supposed.

Williams was one of the first to draw attention to the disturbance of general health which occasionally follows irradiation. In cases where there is no ulceration he advises the drainage of the tumour, so as to permit the discharge of the secretion, and thus obviate all danger of toxæmia.

The subject is also discussed in *Skinner's* work on the treatment of malignant tumours by the X-rays. He says: 'The treatment of malignant tumours by the X-rays is often followed by rigors and elevation of temperature, due to toxæmia. This phenomenon is probably due to the development or liberation of toxins during the degeneration of tissue which has been invaded by the neoplastic growth. The toxæmia is occasionally of sufficient intensity to poison the nervous system, and to kill the patient. It is well therefore to be circumspect in the conduct of such cases.'

In a report published in 1903 he expresses himself thus on the subject of the metastases which have been attributed to the action of the rays:

'The question of the action of the X-rays is still *sub judice.*

Some authorities consider that they facilitate metastasis, while others are equally certain that they have no such action.'

Most authorities are agreed that the X-rays *per se* are incapable of producing metastasis.

In March, 1904, *Oudin* reported to the Société de Dermatologie some accidental complications set up during the course of X-ray treatment. He says: 'In all cases of cancer which I have treated I have observed symptoms of general infection after the third or fourth exposure. There is pain in the back, lassitude, slight fever, loss of appetite, vomiting and diarrhœa, a drawn look in the face, and occasionally cough and dyspnœa. It may be objected that these symptoms are due merely to the absorption of toxins. There is, however, at the same time a notable diminution in the volume of the tumour. In cases where no ulceration exists this must be accompanied by the absorption of solid débris into the circulation. If the irradiation is not too intense, and is intermitted after two or three days, the symptoms rapidly disappear. The treatment may be recommenced after a time, but it is well not to push it to the point where a second infection may be produced.

'At the present time I have under treatment a case of cutaneous and glandular recurrence after removal of the breast. In this patient marked symptoms of infection are produced whenever a longer irradiation than four minutes is given. I am quite certain that if I pushed the treatment, and did not suspend the irradiations so as to give time for elimination, I should set up serious visceral complications, or even general miliary infection.'

S. Mendes, *Da Costa*, and *T. Passtows* consider that the X-rays may have an injurious effect in certain cases. Not only do the rays, in their opinion, produce no modification of the disease, but they seem to stimulate a more rapid extension.

In support of their theory, they adduce two cases. The one was a case of epithelioma in a syphilitic patient. Radiotherapeutic treatment was followed by intense reaction and the disappearance of the epithelioma, but an enormous ulcer formed in the region which had previously been cured by specific treatment.

In the second case the X-rays produced an aggravation of an epitheliomatous ulcer, which was followed by cachexia and death.

More recently our colleague *Dr. Haret* has reported three cases of non-ulcerated cancer of the breast which have manifested toxæmic symptoms after irradiation.

In each of the three cases toxæmic symptoms appeared after the absorption of a dose of 15 H. to 17 H., and this whether the method was that by massive doses or minimal doses frequently repeated.

The patients complained of headache, vertigo, anorexia, insomnia, and general lassitude. In one case a slight rise of temperature was noted.

These phenomena diminished when the treatment was suspended, to reappear in all their intensity when the irradiations were recommenced. They entirely ceased when *Dr. Haret* changed his mode of treatment and gave much shorter exposures.

On the other hand, it should be noted that no such morbid phenomena occurred in the vast majority of cases. They can therefore hardly be considered as a contra-indication of the treatment.

In *Oudin's* cases the complications arose in cachectic patients in the last stages of the disease. The author, moreover, does not mention the dose, so that it is difficult to determine under what conditions the injurious effects of the X-rays first showed themselves. The observations of *Mendes* and *Da Costa* are not very reliable. The symptoms were apparently due to a widespread radiodermatitis rather than to the legitimate action of the X-rays.

The symptoms, moreover, appear to be nervous in their origin. Many women suffer from migraine after a visit to their dressmaker or coiffeur. The horizontal position, the noise of the interruptor, apprehension, and other nervous factors, have a great deal to do with the supposed ill-effects of the rays.

The X-rays have been accused of displacing the cancer cells and disseminating them over the organism. This supposition is quite gratuitous, and has never been demonstrated by histological examination. It is, moreover, contradicted by *Exner's* experiments, and we may assert that there is not the least authority for any such hypothesis.

There only remains the famous 'cancer juice,' of which so many people speak, and which may be readily observed on the surface of a section of a cancerous tumour.

The first effect of the X-rays is to augment the secretion of the wound. What is the nature of the liquid discharge? Chemical analysis alone can enlighten us on this question, but it is probably

a serous liquid of highly toxic nature secreted by the cells of the neoplasm.

Where there is no ulceration and no communication with the exterior, hypersecretion will still occur under the influence of irradiation, but there will be no means of drainage. The secretion must therefore be poured out into the circulatory channels, and may thus produce symptoms of toxæmia, which will continue until the toxins have been eliminated from the general circulation.

In our own experience we have never met with such cases, but *Haret's* observations compel us to regard such complications as possible.

Patients with large masses of cancer should be carefully watched, and if any symptoms of toxæmia appear, the treatment should be suspended. In some cases it may be wise to drain the tumour, as recommended by *Williams*.

Pathogenesis—Histological.

Microscopical examinations have frequently been made of sections of neoplasms which have been treated by the X-rays.

Scholtz was one of the first to examine a section of human skin excised from a neoplasm undergoing regression. It was an epithelioma of the nose, in which the X-rays had produced necrosis. The first piece was excised at the commencement of reaction, and the second piece after the appearance of superficial necrosis. 'Microscopical examination,' he says, 'proves that under the influence of the X-rays the cancer cells degenerate and disappear, just as normal epithelial cells do under similar circumstances. The degeneration, especially in the deeper layers, was only noticeable after a series of intense irradiations.

'In one instance a piece was excised after eight irradiations of ten minutes, at a distance of 10 inches. The specimen was fixed by Fleming's method, and stained with safranin. There were numerous areas of mitosis, but the normal process of karyokinesis was nowhere visible. The cells were filled with filaments of chromatin, of variable size and irregular distribution, but there was no sign of normal division. The appearance was rather one of chromatolysis.'

In other specimens the author observed a marked process of degeneration in the cancerous foci.

The observations of *Mikulicz* and *Fittig* are even more conclusive. They examined a piece of skin excised from the cicatrix of a cancer of the breast, which had been treated by the X-rays. There were no carcinomatous cells, but the subcutaneous tissue was infiltrated with round cells.

The following are *Pusey's* observations on the subject: 'The alterations produced in cancer tissue by the X-rays are of great interest. Examination of superficial neoplastic tissue shows that at the beginning of the treatment only the cells at the circumference of the diseased foci are attacked.

'Their outline becomes indistinct, and the nuclei break up. The scattered nuclear débris is feebly stained by hæmatoxylin. The bloodvessels in relation with the diseased tissue are attacked by endarteritis and obliterated, while those which are at a distance from the cancerous foci remain unaltered.

'Sections were made of a cancerous ulcer, after the raised edge had become flattened and had lost its nodular appearance under treatment. In these similar modifications were observed, but more accentuated.

'There is no longer any trace of cancer. Under the epidermis there is a layer of fibrous tissue, in which are zones which stain pale blue with hæmatoxylin. These are evidently composed of cell and nuclear débris. The carcinomatous infiltration has been replaced by connective tissue.

'To resume, the first alteration takes place in the periphery of the little islands of carcinomatous tissue, and the process gradually spreads from the circumference to the centre. The cells exhibit various stages of degeneration, and disappear gradually by a process of cytolysis, which is followed by the absorption of the débris. The small vessels which are in close relation with the tumour are obliterated by a process of endarteritis.

'The X-rays primarily affect the morbid cells themselves. At first the cellular activity is stimulated, but if the action is maintained, the cells degenerate.

'The epithelial structures are the first to be influenced, next the vessels, and lastly, but in a lesser degree, the whole of the cells of the irradiated area.

'The cure is completed by the absorption of the diseased cells, and their replacement by connective tissue, the healthy stroma being left in all its integrity.'

Perthes has investigated the radiotherapeutic treatment of carcinoma. The cancer cells fuse into a uniform protoplasmic mass with irregular contour, while the nuclei become less and less chromatophile. Leucocytes and connective tissue cells make their appearance in the homogeneous mass, and penetrate any cancer cells that may remain. At a later stage the carcinoma appears surrounded and partitioned by connective tissue, which is infiltrated with small cells. In the meshes of this connective network may be found fragments of the neoplasm, or isolated cancer cells, in a state of degeneration. Finally, there is total disappearance of the elements characteristic of cancer.

A. G. Ellis in his observations on the treatment of cancer concludes: 'Under the influence of the X-rays there occurs a necrosis of the parenchyma and stroma of the tumour, with proliferation of the elastic tissue. In the smaller bloodvessels a homogeneous deposit occurs, which may cause complete obliteration of the lumen. The X-rays produce two principal effects—viz., obliterating endarteritis and cellular necrosis. These effects are simultaneous, and do not depend on one another.' The destructive action of the X-rays is less noticeable in cancerous tumours. He therefore recommends a preliminary treatment by curetting.

Dr. Batten has published the results of a microscopical examination of a scirrhus of the breast treated by the X-rays. The patient had been previously operated on by *Hutchinson*.

Soon after the commencement of treatment the pain ceased, and in three months the tumour had entirely disappeared. The patient remained cured and in good health for four months, and then died from septicæmia, caused by the sting of an insect. A fragment of the skin and hypodermic tissue was excised, and a histological examination was made by *Dr. J. Galloway*.

1. The epithelium was thinned, but the various layers were quite distinguishable. In the stratum mucosum three of these could be made out, the deepest of which—the palisade layer—was more irregular than usual. The cells of the stratum mucosum were normal. The stratum granulosum was not very distinct. Its cells, few in number, were scattered over the subjacent epithelium. Seen in section, there were intervals between the cells, which were, however, numerous enough to allow of the formation of a complete living layer. The cells of the stratum corneum were well cornified, and formed a complete layer, although the cells

were not so close together as normal. There were no interpapillary extensions of the epidermis, and the papillæ themselves had almost entirely disappeared.

2. The corium showed bands of connective tissue interspersed with nuclei, giving it a somewhat cicatricial appearance. The papilla had almost completely disappeared, the surface of the corium having a slightly undulating appearance. Near the surface were foci of leucocytic infiltration, showing that there had been some inflammatory reaction. There was no enlargement of the vessels of the epidermis.

In no portion of the section were there any signs of cancer tissue.

The general aspect was that of a fragment of skin which had undergone atrophic degeneration after a slight degree of inflammation.

This case is of great interest, since it is the only one where an autopsy has been performed after the cure of a malignant tumour by X-rays.

Skinner has given a detailed résumé of the hypothesis put forward to explain the cure of malignant tumours by the X-rays. These are four in number:

'The first hypothesis is that of stimulation of the reparatory forces by the inflammatory reaction. This is not a satisfactory explanation. In some cases, it is true, dermatitis seems to hasten the cure, and in others no improvement occurs before the production of inflammatory reaction; but in the great majority of cases the cure occurs without any signs of dermatitis. The curative action of the X-rays in cancer is not due to any cauterizing action, since it extends to deep-seated tumours, which are shielded from all inflammatory reaction.

'The second hypothesis is based on the supposition that the Roentgen rays have a selective action on tissues of an aberrant type, which possess but little vitality.

'It is not to be denied that a destruction of diseased tissue does sometimes occur under the action of the rays, and that it may be accompanied by symptoms of toxæmia. It is not, however, universal, as it should be if it were an essential factor of the cure.

'According to the third hypothesis, cancer is a parasitic disease, and the X-rays destroy or hinder the development of the parasites.

'To this it might be objected that if cancer were caused by a pathogenic organism, which was easily destroyed by the X-rays, all cases of cancer should be curable by irradiation. Unfortunately, clinical experience teaches us that this is not the case. It may be, however, that the X-rays are not destructive to the parasite itself, but in some way modify the tissues, so as to prevent its development. A belief in the radiotherapeutic cure of cancer is in no way incompatible with the theory of the parasitic origin of cancer.

'According to the fourth hypothesis, malignant degeneration is due to a depression of normal protoplasmic activity. This results in a regression of cell structure towards a more primitive type, and depends on a profound constitutional idiosyncrasy, coupled with a long-continued local irritation. In the energy of the Roentgen radiations we find a vibratory period, wave-length, and amplitude of oscillation, suitable to affect the molecular movements of the cells, recalling them to their normal function, and enabling them to overcome the tendency to aberrant development.

'On this hypothesis the clinical results of treatment should be as follows:

'We should expect to find that radiotherapy would at once arrest the invasion of healthy tissue, since the peripheral cells, with less tendency to degeneration, would be much more easily influenced by the rays. The focus of disease would be encapsuled by a zone where the tendency to degeneration had ceased, and the normal development obtained. This focus of degeneration would be like a foreign body, to be absorbed or ejected by the normal tissue. The efforts of the organism to get rid of the diseased mass would result in atrophy, absorption, or enucleation of the tumour. The termination of the case would depend on the personal equation of the patient as regards his susceptibility to the action of the X-rays.'

Skinner considers that clinical experience is in accordance with this theory.

The Roentgen rays appear to have a selective action on epithelial tissue.

Scholtz has shown that under the action of the rays epithelial tissue undergoes a process of slow and progressive degeneration. This is accompanied by inflammatory phenomena, with migration

en masse of the leucocytes, which complete the destruction of the degenerating cells.

In this way we may explain the action of the X-rays on the skin, since it is composed of precisely those elements on which they have the greatest selective action. It is difficult to understand why the action should be confined to diseased tissue, without spreading to the healthy stroma, which is composed of cells of a similar nature.

It has been supposed that young cells are particularly sensitive to the Roentgen rays, and this is probably the case.

Professor von Bruns of Tubingen has furnished us with another explanation. In his work published in the *Therapie der Gegenwart*, he gives the following quotation from Virchow:

'In itself carcinoma is not a durable tumour. Its cells have all the characters of decrepitude and fragility, so that their vitality is limited, and they soon begin to show signs of retrogressive metamorphosis. If at the outset they were able to destroy this degenerating tissue and prevent the formation of accessory nodules, we should be sure of permanently curing the disease.'

Bruns considers that the curative action of the X-rays depend upon the fact that they favour the spontaneous tendency to degeneration which characterizes every cancer cell.

In *La Presse Médicale*, *Romme* has an article on this question, in which he quotes *Ribbert* of Göttingen:

'The cancer cell is, by the condition of its nutrition, more feeble, less resistant, and less highly vitalized than the normal cell. It is this inferiority that explains the elective action of therapeutic agents of all sorts on cancer tissue. Any interference with the circulation, or any modification of the blood by drugs, such as quinine or arsenic, will tell more forcibly on the feeble resistance of the cancer cell. The normal cell will react, and adapt itself to its new conditions of existence, whereas the cancer cell will succumb and be destroyed.' This is *Ribberts*' explanation of the action of radiotherapy and bacteriotherapy, and the various chemical and physical agencies which destroy the feebler cancer cells, while leaving intact the normal tissue.'

Exner has studied the action of radium on cancer. He compared sections excised from a lesion before and after treatment, and found that after irradiation with radium the neoplastic growth was transformed into connective tissue in the course of a single

week. During the whole course of treatment the hyperplasia of the connective tissue became more and more accentuated.

A modification of the cancer cells became apparent in about fifteen days. The proliferation of the connective tissue broke up the nodule into small groups of cancer cells, ultimately choking them completely.

At the end of the first week of treatment there was no apparent alteration of the cancer cells, although the connective tissue was growing rapidly. Hence we must consider that the cure is brought about by the mechanical choking of the cancer cells by the proliferating tissue.

Schwartz, working in *Holzknecht's* laboratory, carried out a series of experiments on the degrees of sensitiveness to the X-rays shown by the cells of various tissues in health and disease. In this investigation he used the radiations of radium, which are similar in their action to the X-rays.

On exposing a hen's egg for a month to the action of radium, he found that the yolk had undergone profound alteration. This was associated with the decomposition of lecithin and the production of methylamin.

Lecithin is a constituent of all cell-tissue which is developing or awaiting development. It is found in the spermatozoa, the yolk of eggs, in neoplastic growths, in fungi, and in the embryo of plants.

In *Schwartz's* opinion the action of the X-rays is due to the decomposition of the lecithin in the cells. Hence it will be more marked on those cells which contain a considerable quantity of this substance.

Further chemical investigation is necessary before we can accept this explanation entirely. In conclusion, we may say that the X-rays exercise a special action on certain cancerous cells, causing their degeneration and absorption, but that the mechanism of the action is still unknown.

Conclusions.

In certain cases radiotherapy has produced a complete cure of all the objective symptoms of cancer.

Most cases of cutaneous epithelioma are modified or apparently cured by this method. Recurrence is probably less frequent than

after surgical operation, although we cannot as yet speak positively on this subject.

Any elevated growth of the skin should be removed by surgical means before proceeding to radiotherapeutic treatment.

Primary cancer of the breast, or of deeply-seated organs, should be removed by an operation. This should be followed at once by irradiation. The treatment should be radio-surgical.

Where an operation is refused, X-rays may be employed with some hope of success, but a cure is very rare.

If the neoplasm is small, superficial, and without glandular enlargement, either of the two methods may be employed, but the preference should be given to surgical interference.

In inoperable cases great service may be rendered by the X-rays, which alleviate pain, ameliorate the general health, and prolong life. They are, in fact, the best palliative agency we possess.

In cases of recurrence after operation radiotherapy gives better results than surgery. In all cases where the cutaneous nodules are not too large radiotherapy should be tried before having recourse to surgical interference.

A successful result is more probable when the glands are but little affected.

Cancerous ulcerations, either primary or secondary, heal rapidly under the influence of the rays. The cicatrix has the appearance of healthy skin.

Certain cases of cancer seem to be refractory to radiotherapeutic treatment, although they are in appearance similar to the forms which are amenable to the X-rays.

Toxæmia, if it ever occurs, is very rare.

In the present state of our knowledge we are unable to say whether the cure is permanent or only apparent. In a certain number of cases there has been no recurrence after several years.

The regression of the neoplasm is independent of radiodermatitis, although in some cases the tumour does not diminish in size until it has absorbed a dose of rays sufficient to set up more or less erythema.

The treatment should be stopped on the appearance of slight erythema. This degree of reaction should only be exceeded in exceptional cases.

Accidental dermatitis may be avoided by a careful technique and an accurate system of dosage.

We possess in the X-rays a valuable means of determining the recession of neoplastic growth. It may be hoped that with greater knowledge and more perfect technique there are many surprises in store for us in the treatment of cancer by radiotherapy.

CHAPTER X

VARIOUS DISEASES

This chapter will treat of those affections in which radiotherapy has given varying results, and in which as yet our experience is not sufficient to determine its value with any degree of certainty.

Nævus.

Radiotherapeutic treatment has been used in the treatment of nævus without much success.

According to *Brocq* these lesions may be divided into two classes—pigmentary and vascular. The first division includes nævus spilus, nævus verrucosus, and nævus hypertrophicus.

In nævus pilaris the X-rays may be employed to destroy the hairs.

The hypertrophic and warty forms are also often ameliorated. In these varieties, however, electrolysis acts with greater certainty, whereas it is unable to affect the pigmentary and vascular form for which radiotherapy is indicated.

Gocht has reported successful cases, and *Scholtz* obtained a temporary cure of nævus pigmentarius by setting up superficial necrosis. Some time afterwards, however, the pigmentation partially recurred.

Jutassy treated a case of nævus vascularis by this method. It was a so-called 'wine-mark' extending over one half of the face and the mucous membrane of the mouth and nose. A considerable dose of the rays was given, setting up a violent reaction of the whole surface, accompanied by desquamation and the formation of crusts. When the epidermis was renewed, it was of normal colour, and eighteen months afterwards there had been no relapse. The author attributes this result to the action on the blood-

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vessels, which were successively contracted, inflamed, and obliterated under the influence of the rays.

Scholtz at the Breslau Hospital was less fortunate, and failed in his endeavour to cure vascular nævus by radiotherapy.

Dickson of Toronto reports a successful cure of nævus vascularis.

Pfahler considers that the results of radiotherapeutic treatment are at least equal to that obtained by other methods. It is in most cases necessary to produce ulceration of the skin, which is not well borne by the patients.

At the Broca Hospital we treated a young girl for a 'wine-stain' which occupied the whole of one side of the face.

The case had been previously treated by electrolysis and phototherapy without result. Moderate irradiations produced no appreciable alteration of the colour of the skin

Determining to act more energetically, we told the patient that it was necessary to set up a more violent reaction.

With her consent we produced a violent dermatitis with exfoliation. A dose of 10 H. with No. 4 rays was employed, with the result that phlyctenulæ and desquamation occurred. The healing of the skin took a month to complete. The new tissue is slightly cicatricial, but it is only a little redder in colour than the healthy skin. In certain spots, however, where the reaction wa less intense the colour is deeper, and a fresh irradiation may be required to complete the cure.

The present is a vast improvement on the original appearance, and we have every reason to hope that the case will prove a complete success.

The above case seems to indicate that it is necessary to set up a reaction sufficient to produce desquamation. There is, however, danger in acting too energetically, and producing a cicatrix still more disfiguring than the original disease. A dose of 10 H. should never be exceeded in any one exposure.

Where electrolysis gives good results it should be preferred to radiotherapy, since the application of the former is simpler, less expensive, and safer.

Intertrigo.

Williams has seen good results in the treatment of this affection by radiotherapy.

It is not easy to understand what this author means by the

term, since in France intertrigo is a symptom rather than a disease.

Herpes Zoster.

Williams reports two cases treated by this method.

The first was improved by a single application, but the patient had to abandon the treatment on account of business affairs.

In the second case a slight irradiation relieved the sensations of burning and pain. The treatment was then intermitted, with the result that the pain returned. A second irradiation caused it to disappear entirely.

In the course of radiotherapeutic treatment for cancer of the breast, one of our patients suffered from an attack of herpes zoster, the pain of which did not appear to be influenced by the treatment. It is true that the irradiations were directed on the cancerous tumour rather than on the course of the affected nerve. Moreover, the presence of the two diseases may have complicated the result.

Xeroderma Pigmentosum.

Jamieson has reported the successful treatment of this affection in the case of a child twelve months old. The disease had commenced on the ala of the nose and gradually spread over the face. After eighty-four irradiations an attack of dermatitis was set up, and the lesion disappeared.

Allen reports a case of generalized xeroderma in which both eyes were affected. One had been destroyed, while the other was saved, thanks to the intervention of the X-rays.

Other observers have failed to procure any amelioration by this method.

Kraurosis Vulvæ.

In 1903 *Stower* (Denver) published a case of a woman who was treated by the Roentgen rays for this affection. The patient was fifty years of age, and the treatment was not followed by any amelioration. The lesion was aggravated, and the irradiated region was attacked by an erythema of an erysipelatoid character. A fortnight later the diseased areas on the labia and vaginal mucous membrane mortified and sloughed.

We suspect that this result was due to an exposure of too great intensity. No measurement of the dose is given in the report of the case.

Chronic Ulcer.

In view of the stimulant action of the X-rays on cellular activity, radiotherapy has to produce the cicatrization of chronic ulceration.

Encouraging results have been recorded by many observers. As a result of two months' radiotherapeutic treatment, *Dr. Gautier* of Paris obtained the cicatrization of an obstinate varicose ulcer, which resisted all other modes of treatment.

Sjögren and *Sederholm* also report satisfactory results from the use of X-rays in the treatment of chronic ulcer. Healthy granulation was produced, the ulcer improved in appearance, and cicatrization speedily ensued.

Taylor reports the case of a child with ulceration of the arm consequent on a burn. The wound was partially healed, but the cicatrix was hard, and of a keloid consistence. A short series of irradiations was followed by the complete healing of the ulcer, and a considerable improvement in the appearance of the scar.

Colleville has treated a varicose ulcer, and *Sequeira* a perforating ulcer, with equally good results.

We have not ourselves had sufficient experience to be able to give an opinion on the matter. We are making some experiments on the subject, and hope soon to be able to report definitely on the value of radiotherapy in the treatment of chronic ulcers. The lesion requires active treatment, and we may safely give doses of 7 H. to 8 H. every fortnight or three weeks, diminishing the quantity gradually as soon as healing has commenced.

Bacillary Adenitis—Scrofuloderma.

Grouven, *Aronstam*, and *Zeisler* have obtained as good results in the treatment of scrofulous lesions as in cases of lupus.

Iwar Bagge has cured a case of tuberculous ulceration by this method, and *F. B. Bishop* has obtained some remarkable results, especially in cases of suppurative adenitis. His cases are published in the Report of the Congress of the American Electrotherapeutic Association of 1902.

Williams speaks favourably of the treatment, and *Beresford Childs* reports a case of tuberculous ulceration of the neck which disappeared under the treatment.

Briggs has had similar results.

Frank Vale obtained by this means the diminution of an adenitis which a microscopical examination showed to be of bacillary origin. The tumour was reduced to half its size, and the general health and strength of the patient was greatly improved.

The irradiations were repeated twice a week, with a duration of fifteen to twenty minutes on each occasion.

In our hands the results were not so satisfactory in a case of tuberculide of a papulo-necrotic character, which simulated lupus. At the beginning of the treatment there was some improvement, but this did not continue.

Bacillary Osteitis, Arthritis, and Tubercular Rheumatism.

Radiotherapy has furnished good results in the treatment of bacillary osteitis (spina-ventosa). *Béclère* treated by this method a finger attacked with tubercle of the bone, with fistulous openings. The cure was complete. The patient was subsequently shown to the Surgical Society.

Rays of considerable penetration should be used, with doses varying from 4 H. to 5 H., repeated once a week. The lesion may be advantageously attacked on all sides.

Reboul communicated to the Congress at Grenoble a case of tuberculous rheumatism cured by the X-rays.

Under the influence of the rays the pain was rapidly relieved. This was followed by a diminution of the œdema, and the thickening and stiffness of the wrist, hand, and fingers. The treatment began in January, in the beginning of February the patient could move his fingers and wrist, and he resumed his work in March.

Sokoloff has also obtained good results in cases of acute rheumatism.

Tuberculous Warts.

Ullmann asserts that the results of radiotherapy in this affection are better than those obtained in the treatment of lupus vulgaris.

Campbell reports several cases of cure, and *Zeissler* has treated three cases affected with this disease with good results.

Pulmonary Tuberculosis.

Rendu and *Du Castel* observed a considerable improvement from the X-rays in the case of a young man suspected of tuberculosis. As a result of their observation a number of investigations were made by many experimenters in different countries.

The amelioration obtained was in most cases only of a temporary character, and was probably due to the effects of suggestion, to which tuberculous patients are unusually susceptible.

The radiodermatitis following irradiation may in some instances have acted as a vesicant, and caused some improvement by its revulsive action.

At the present time the treatment has fallen into disuse, as the results were absolutely negative.

Congenital Ichthyosis.

Skinner has published some observations of a case of ichthyosis, in which one hand was treated by the inunction of ointment and the other by the Roentgen rays.

The latter was rapidly improved, the skin becoming soft and smooth, whereas the former was in no way altered. Unfortunately, dermatologists are not agreed as to the nature of the affection to which the name of congenital ichthyosis has been given. We cannot be sure of the exact nature of the case reported by *Skinner*.

Elephantiasis.

Sorel and *Soret* have cured a case of elephantiasis of the hand accompanied with general disturbance of the nervous system.

The case is reported in *La Normandie Médicale* of March, 1898, and more in detail in a thesis by *Sorel*, published in 1903, and illustrated by photographs.

The cure was accidental, and resulted from repeated radiographic exposures, made with a view of studying the condition of the osseous system in this disease.

This observation, although quoted by many authorities, is far from being conclusive.

Pemphigus Foliaceus.

Scholtz has treated by this process a case of pemphigus foliaceus. The wide extent of the malady renders radiotherapeutic treatment most difficult of application.

Rhinoscleroma.

In 1902 *Dr. Gottstein* reported a case of rhinoscleroma which had been greatly improved by radiotherapeutic treatment. The patient was shown to the Silesian Society of Oto-rhino-laryngologists.

Fittig has also obtained good results in this affection.

Rhinophyma.

Strebell reports the cure of a patient affected with this disease. We had the opportunity of treating a case of rhinophyma of two months' duration in consultation with *Dr. Béclère* at St. Antoine.

The nose was of great size, club-shaped, and of a reddish-violet hue, the colour extending over the cheeks.

Rays of feeble penetration—No. 5—were used.

The case was irradiated twice in the course of a week, with a dose of 3 H. on each occasion. Reaction occurred in about ten days. The nose became of a mulberry-red colour, but appeared to be softer. After the reaction had subsided, two further irradiations were given at intervals of a week. At this time the nose had not greatly diminished in volume, but it was softer, and the colour was not so deep. The patient left the hospital, and we lost sight of him.

The case is incomplete, but there is some evidence that this disease is favourably influenced by the rays.

Hyperhidrosis.

The well-known atrophic influence of the X-rays on the glands seems to be an indication for their use in cases of hyperhidrosis.

In 1903 *Pusey* drew attention to a case of hyperhidrosis of the axillæ, in which great improvement followed treatment by X-rays. His were the first observations published on the subject.

Engmann considers it necessary to produce erythema and even alopecia in the treatment of hyperhidrosis of the axillæ. By this means he obtained good results, and the improvement continued for many months.

In January, 1904, *Bulkley* reported three successful cases. These are in perfect accord with the physiological results of irradiation, and we consider that it is a useful mode of treatment in this affection, although one which will rarely be required.

The dose should not exceed 4 H. for each application. The irradiation should be given with great caution, as the articular folds are very sensitive to the action of the rays.

Exophthalmic Goitre.

Williams cites a case of exophthalmic goitre greatly ameliorated by radiotherapy. The thyroid body diminished in volume, and the general health was improved. The following were the measurements of the thyroid :

Right lobe ... 2 centimetres by 4 centimetres.
Left lobe ... 5 centimetres by 8 centimetres.

After five applications, these dimensions were reduced to :

Right lobe ... 1½ centimetres by 2 centimetres.
Left lobe ... 3½ centimetres by 4 centimetres.

These results are very encouraging.

Hydatid Cyst of the Liver.

Diaz de la Quintana reported the cure of a hydatid cyst of the liver by means of the X-rays.

He gave forty-seven séances, each of ten minutes' duration, at intervals of a week.

Uterine Myoma.

Deutsch of Munich reports considerable diminution in the size of benignant tumours of the uterus as a result of irradiation of the abdomen.

Paget's Disease.

Meek reports a case of cure of this affection. Other observers have not been so successful. *Stelwagon* failed in the cure of a patient suffering with this disease in the eczematous stage.

Bisserié has kindly furnished us with notes of a case of Paget's disease in the ulcerative stage, in which the whole nipple was involved. Ten applications were made, in groups of two, at intervals of a fortnight. A dose of 8 H. was given in each series, and this was diminished to 6 H. towards the end of the treatment. After the fourth application the case began to improve, and the improvement continued steadily. The cure was completed by the end of November, and up to the month of March there had been no recurrence.

A case under our care was treated by a dose of 4 H. or 5 H. repeated once a fortnight. No violent reaction resulted, and the case was ultimately completely cured.

Syphilis.

It is usually asserted that syphilis lesions are refractory to the X-rays. Some authorities even declare that they aggravate the disease. Recent observations, however, seem to show that this idea is exaggerated. *Morton* reports the case of a patient suffering from a tertiary lesion which was incurable by ordinary means, but which improved slowly but steadily under radiotherapeutic treatment.

It would seem that syphilitic lesions are less readily influenced by the rays than non-specific affections of a similar character.

Epilepsy.

Acting on the idea that X-rays exercise a stimulating action on organic metabolism, *Branth* tried radiotherapy in the treatment of epilepsy, employing irradiations of five minutes' duration at a distance of 16 inches.

In every instance there was a diminution in the violence of the crises, and of the prostration which succeeded them.

At the Congress of Grenoble *Leduc* read a paper on this subject.

As a result of some experiments on rabbits, he concluded that the X-rays would exercise beneficial effect on epilepsy.

One patient treated by this method was greatly improved. The number of attacks was much diminished, a result which had not been attained by any other treatment.

Parapsoriasis.

We have had under radiotherapeutic treatment a curious case, which was at first considered to be one of parapsoriasis. The clinical appearance was that of parakeratosis variegata, although the microscopical examination pointed rather to mycosis.

There were signs of perivascular infiltrations spreading into the papillary body in layers parallel to the surface of the skin. Here and there the infiltration penetrated the deeper layers of the epidermis, splitting them up and producing patches of exocytosis.

The lesions were considerably improved under treatment; there was a change in the colour of the patches, and the infiltrations diminished.

The patient is still under treatment, but the patches which have been irradiated are apparently cured.

The dose varied from 4 H. to 8 H. for each patch at each exposure, with rays of penetration Nos. 4 or 5. We are treating another case of typical parapsoriasis, which has not been sensibly modified by doses of 4 H to 5 H. We propose to increase the quantity to 8 H.

Miliary Dilatations of the Lymphatics—Vitiligo-Keratoderma.

We have lately treated a woman suffering with miliary dilatations of the lymphatics of an epitheliomatous character, accompanied by œdema of the trunk and upper limbs. The patient was shown to the Société de Dermatologie in November, 1903. Radiotherapy did not produce any durable improvement. Some of the lesions on the chest faded away, but the erythematous patches on the back continued to spread. The patient was discharged uncured.

We may allude here to the encouraging results obtained by *Heidingsfeld* in actinomycosis, and by *Williams* in blastomycosis.

Ullmann has obtained good results in cases of vitiligo and hyper-pigmentation, as well as in obstinate vegetations of the glands.

Zeisler has published three cases of palmar and plantar kerato-derma cured by the X-rays.

We have also treated several cases with complete success.

The dose absorbed has been 5 H. to 7 H. at each séance, with an interval of ten to fifteen days between the irradiations.

Two or three exposures have been usually sufficient.

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